COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

April 1956

Linden Generating Station of Public Service (N. J.) Electric and Gas Co. (see p. 69) shown in the architects rendering as it will connect to Esso's Bayway Refinery.

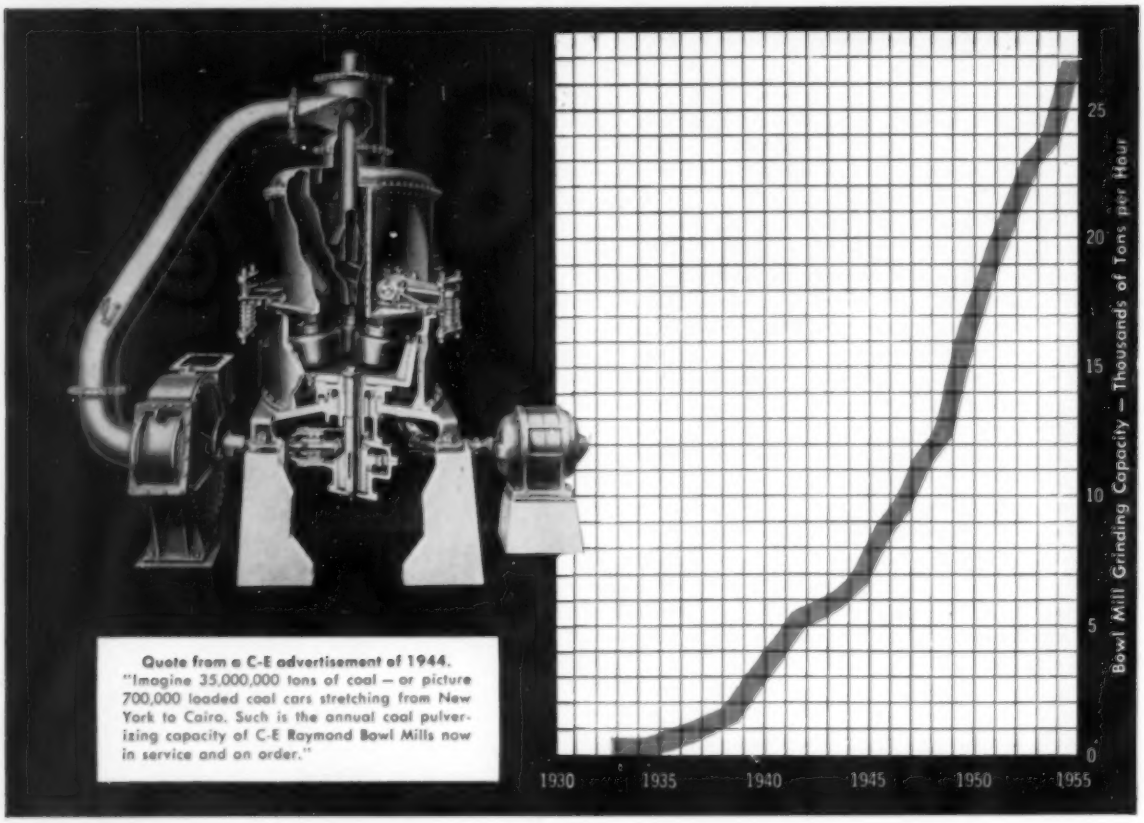
High-Capacity Two Furnace Boilers

Coal Minerals Importance to Boiler Design

Central Station Piping Trends

American Power Conference Review—I

A NEW LOOK AT A NOTABLE RECORD


Quote from a C-E advertisement of 1944.
"Imagine 35,000,000 tons of coal — or picture 700,000 loaded coal cars stretching from New York to Cairo. Such is the annual coal pulverizing capacity of C-E Raymond Bowl Mills now in service and on order."
Bowl Mill Grinding Capacity — Thousands of Tons per Hour
0
5
10
15
20
25
1930
1935
1940
1945
1950
1955

When the paragraph quoted above was written in 1944, the C-E Raymond Bowl Mill had been on the market just 10 years. Obviously it had achieved tremendous acceptance in the power generation field. But see what has happened since. Those 700,000 cars have grown to 2,850,000 which, in a single train, would more than encircle the earth at the latitude of New York.

No one factor could possibly account for this widespread acceptance. Rather it is the fact that the Bowl Mill's record of performance in many hundreds of installations has been outstanding in all these important respects...

- **power consumption**
- **maintenance costs**
- **control characteristics**
- **ability to maintain capacity with wet coal**
- **ability to maintain fineness through life of grinding elements**
- **quiet vibrationless operation**

The Bowl Mill's top performance on *all* these counts is the reason why utility engineers continue to accord it such widespread preference.

Equivalent of 27,200 tons per hour shown on chart.

B-912

COMBUSTION ENGINEERING

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Steam Generating Units • Nuclear Reactors • Paper Mill Equipment • Pulverizers • Flash Drying Systems • Pressure Vessels • Home Heating and Cooling Units • Domestic Water Heaters • Soil Pipe

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 27 **No. 10**

April 1956

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BPA

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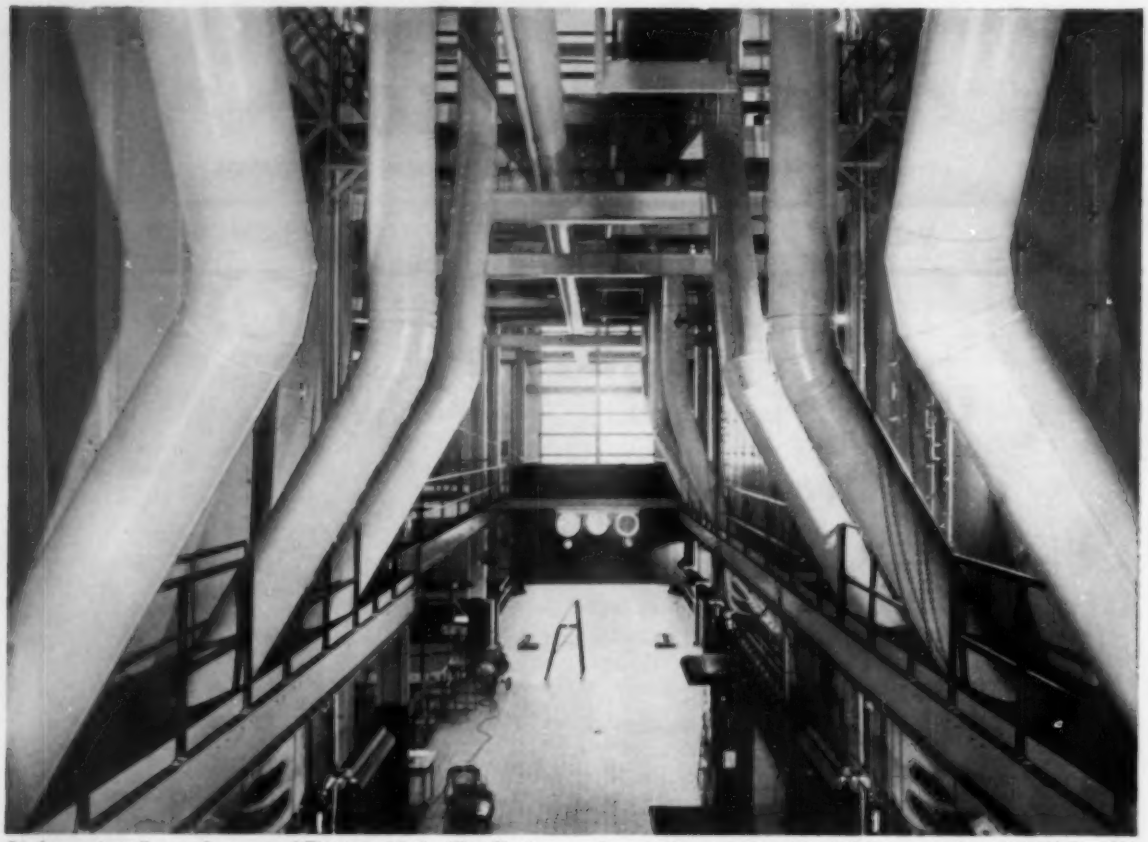

It's happening all over the country! This time it's the West Heating Plant of G.S.A. in Washington, D.C. Six of the nine chutes shown above, each over 25' long by 18" O.D., are of Lukens 3/16" 20% Type 304 stainless-clad steel, purchased to assure free coal flow.

Clad Steel Chosen Again...

STAINLESS-CLAD CHUTES PROMISE FREE FLOW IN G.S.A. HEATING PLANT!

The General Services Administration is replacing worn coal chutes in its West Heating Plant with chutes of stainless-clad steel. In growing numbers, coal handling installations throughout the country are switching to clad steel equipment—because of *these demonstrated advantages:*

- substantial economies through lower maintenance costs in chutes, hoppers, bunker noses, pipes and spreaders.
- toughness proved by *installations 10 years old* which *show no measurable wear!*
- freedom from hangups and the damaging and costly effects of sulphuric acid corrosion from wet coal!
- evidence of service life that matches the life of the boiler!
- *Plus:* ready fabrication . . . the permanence of bond between stainless-clad surface and strong, low-cost carbon steel backing plate . . . over-all quality that delivers lower maintenance costs, longer life and trouble-free operation.

Want performance facts . . . product information to help your engineers make the most of clad steel . . . the names of some of the nation's best and most experienced coal handling equipment builders? Write Manager, Marketing Service, 845 Lukens Building, Lukens Steel Company, Coatesville, Pennsylvania.

STAINLESS-CLAD STEELS

LUKENS

FOR INTERIOR COAL HANDLING EQUIPMENT

LUKENS STEEL COMPANY, COATESVILLE, PENNSYLVANIA

Producers of the Widest Range of Types and Sizes of Clad Steel Available Anywhere

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PITTSBURGH • BOSTON • CLEVELAND • DETROIT • NEW YORK
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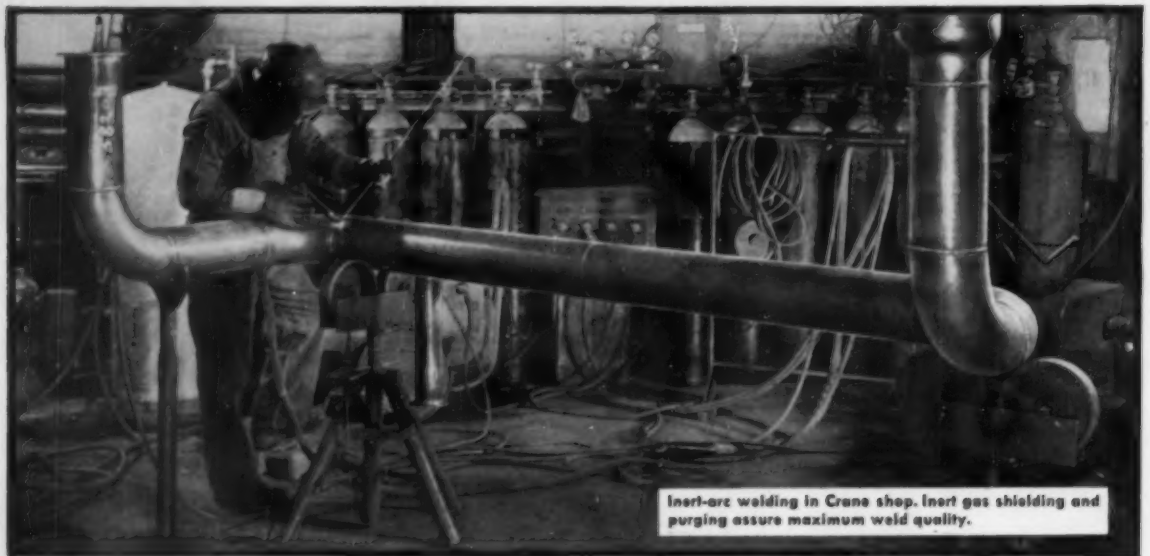
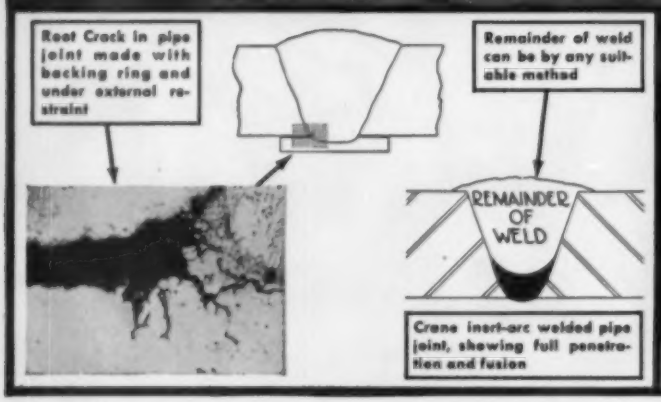
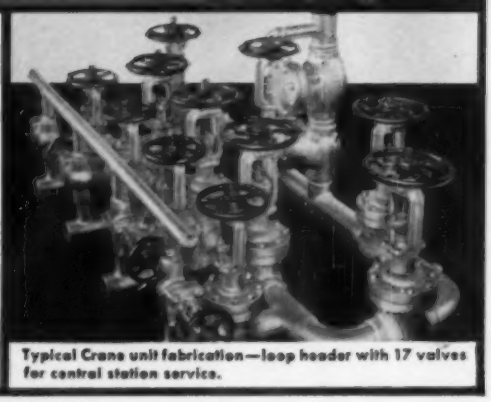
For New England: New England Coal & Coke Co., For Export: Castner, Curran & Bullitt, Inc.



Inert-arc welding in Crane shop. Inert gas shielding and purging assure maximum weld quality.


Root Crack in pipe joint made with backing ring and under external restraint
Remainder of weld can be by any suitable method
REMAINDER OF WELD

Crane inert-arc welded pipe joint, showing full penetration and fusion



Typical Crane unit fabrication—loop header with 17 valves for central station service.

Crane-developed butt-welding technique assures more efficient power piping

Gives important advantages—eliminates backing rings

On shop fabricated assemblies, Crane inert-arc *first pass* welded butt joints are making significant contributions to modern power plant operation.

By eliminating backing rings as used with metal-arc welding, the Crane inert-arc first pass technique assures a high quality weld with smooth root contour without crevices. It eliminates the possibility of basal cracks sometimes associated with backing rings or the characteristics of the base material.

The practicability and dependability of Crane inert-arc *first pass* welding have been thoroughly demonstrated. Leading power plants have been enjoying its advantages for several years, particularly on heavy wall alloy piping for main steam service, and on Schedule 160 carbon steel boiler feed piping.

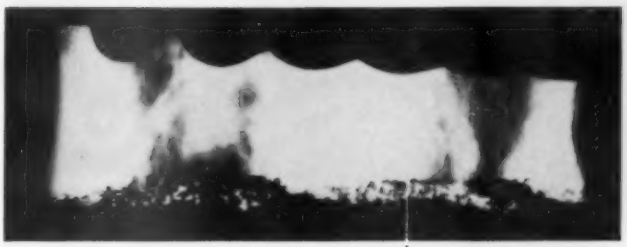
Welding all types of heavy wall alloy power piping is just one of Crane's services to the power industry. Crane handles every phase of unit fabrication for headers, assemblies and valve groupings—simple or complex, large or small. See your Crane Representative for expert assistance on all power piping needs. Write to address below.

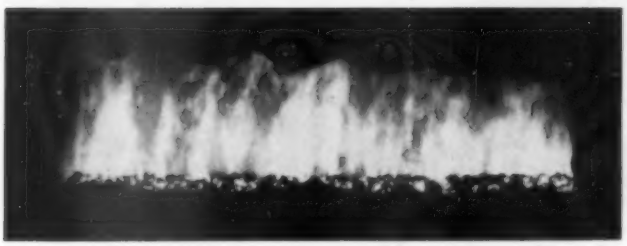
CRANE VALVES & FITTINGS

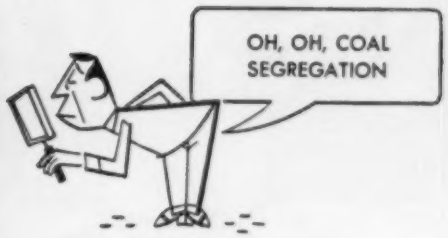
PIPE • KITCHENS • PLUMBING • HEATING

Since 1855—Crane Co., General Offices: Chicago 5, Ill. Branches and Wholesalers Serving All Areas

Look at the fire on your stoker



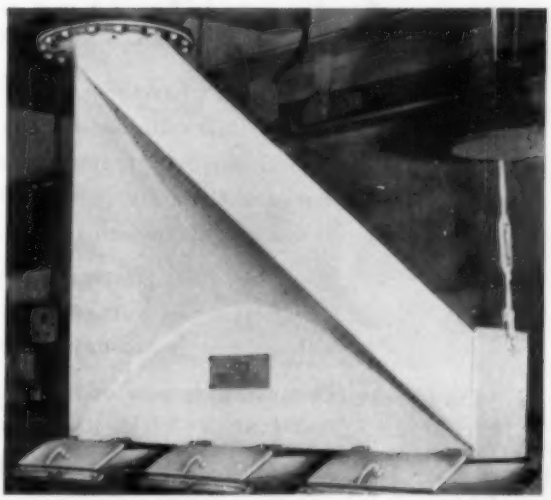




• Coal segregation on your stoker means increased costs due to uneven combustion. Fine coal zones present greater resistance to air flow. Insufficient air means incomplete combustion, unburned fuel in the ash pit. In addition, these zones produce more than the customary amount of smoke.

Coarse coal zones, on the other hand, present less resistance to air flow. More air than required means low CO_2. Also, uncovered stoker iron is exposed to high furnace temperature. Result — expensive repairs and down time.

Take another look at your stoker fire. If you see the tell-tale signs of segregation, you need a S-E-Co. CONICAL Non-Segregating Coal Distributor. This distributor has effectively eliminated coal segregation in hundreds of plants throughout the country. For more information on how you can increase the efficiency and economy of your stoker, write for our Bulletin No. 73. Remember, in scales, valves or distributors, you get more value when you buy S-E-Co.



A graphic description of the principle of the S-E-Co. CONICAL Non-Segregating Distributor (pictured above) is found in our Bulletin No. 73. Write now for your copy.

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Fresh, Clean Ink for a Year of Trouble-free Recording

★ You won't have any messy, time-consuming re-inking of pens on the new Bailey Recorders. The entire system is white-glove clean—hermetically sealed, non-evaporating, non-corrosive. Gone is any chance of sludge or oxide formation. Gone are clogged pens, interrupted records, unsightly splashes.

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This exclusive new inking system* is only one of the many time-saving, money-saving distinctive features of the new Bailey Recorder.

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*Now available for the New Bailey Recorder only.

ONLY BAILEY OFFERS ALL THESE ADVANTAGES IN A SINGLE RECORDER

- Pre-calibrated plug-in receiver units
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- Any four variables on one chart—easily read and interpreted
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FLOW · LEVEL
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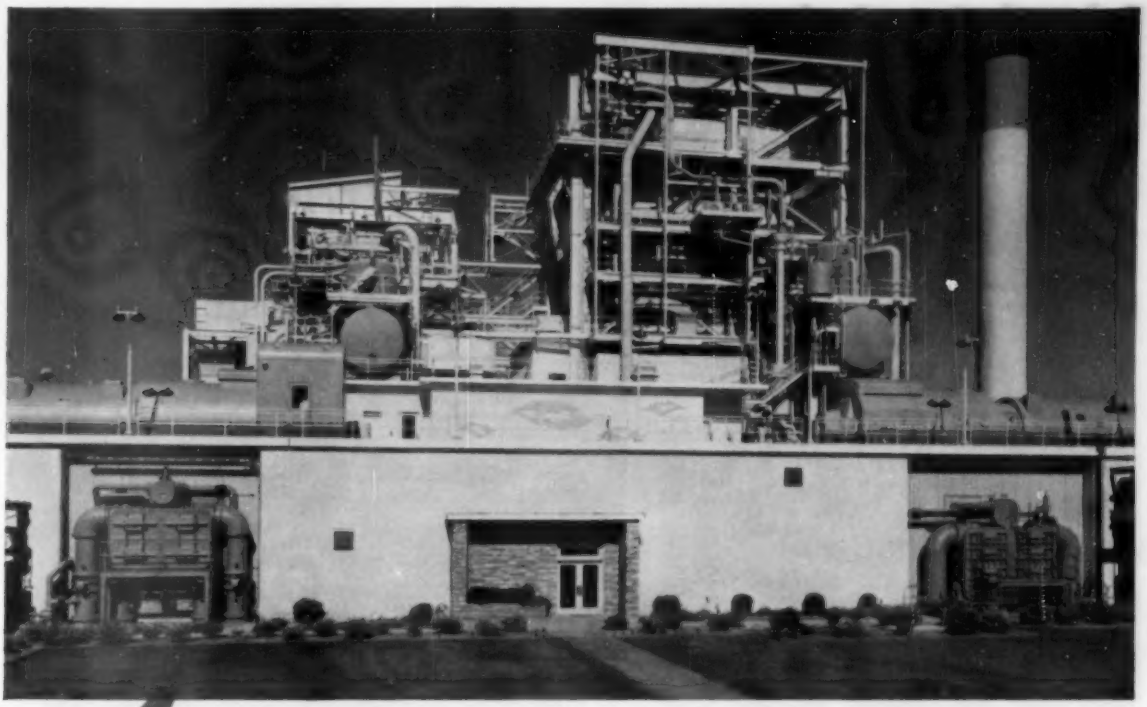

Again KYRENE STEAM PLANT

saves under-turbine space with I-R rectangular condensers

When Unit No. 1 of Salt River Power District's Kyrene Steam Plant went on line in June 1952, its 30/33,000 kw turbine-generator was served by a space-saving 27,500 sq. ft. I-R rectangular condenser, with I-R circulating and condensate pumps.

Now the same economy of under-turbine space has been extended to the newly completed Unit No. 2. Here, at right in photo above, the 60/66,000 kw turbine-generator is served by a 47,500 sq. ft. I-R rectangular condenser—again with I-R circulating and condensate pumps.

Designed and built by the Bechtel Corporation, the Kyrene plant located near Phoenix, Arizona represents the last word in modern, outdoor-type design. To assure maximum continuity of service, all major equipment was selected on the basis of long-range *dependability* in continuous, heavy-duty service. That's one of the vital but unseen features that's built into every item of Ingersoll-Rand steam plant equipment. Ask your I-R representative for complete details on the equipment best suited to your needs.

I-R BOILER-FEED PUMPS serve new generating unit, too

The 642,000 lb. per hr., 1500 psi steam generator for Unit No. 2 is served by the two Ingersoll-Rand high pressure, double-case boiler-feed pumps shown above—each rated 1,560 gpm, 4100 ft. head. Pump speed is flexibly controlled by an automatic fluid drive coupling.

Ingersoll-Rand

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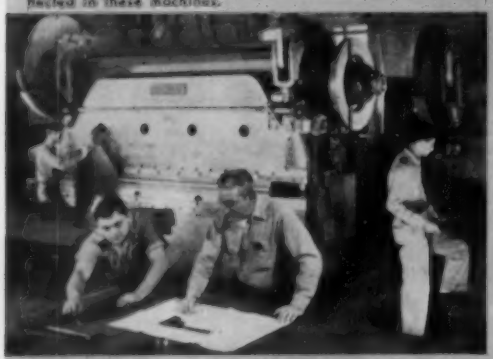
SOUND DESIGN—Richardson Engineers are career men in the design of automatic weighing equipment for all industries. Experience in thousands of field installations is reflected in these machines.



SCALE FABRICATION—Adequate shop facilities and trained workers are "musts" for the fabrication of a quality product.

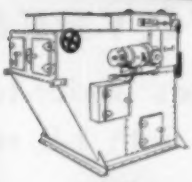
WELDING—Good welds, like these, are the true test of high quality workmanship . . . can withstand the year in, year out impact of 'round-the-clock operation.

PRECISION MACHINING—Knife edges, the heart of the weigh beam insuring long-term accuracy and dependability, are produced on this modern milling machine.

What goes into a Richardson COAL SCALE

Besides COAL?

Here are evidences of the careful engineering and painstaking workmanship that go into every scale, every product manufactured by the Richardson Scale Company. Richardson stands behind its product . . . protects you with sound design, rugged, heavy-plate construction and competent nationwide service. That's why you can specify Richardson Automatic Coal Scales with complete confidence!



In the Power Industry, Richardson Coal Scales have earned a superior reputation for dependability. Send for Bulletin 0352 . . . and learn why.

Richardson

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RICHARDSON SCALE COMPANY, Clifton, New Jersey

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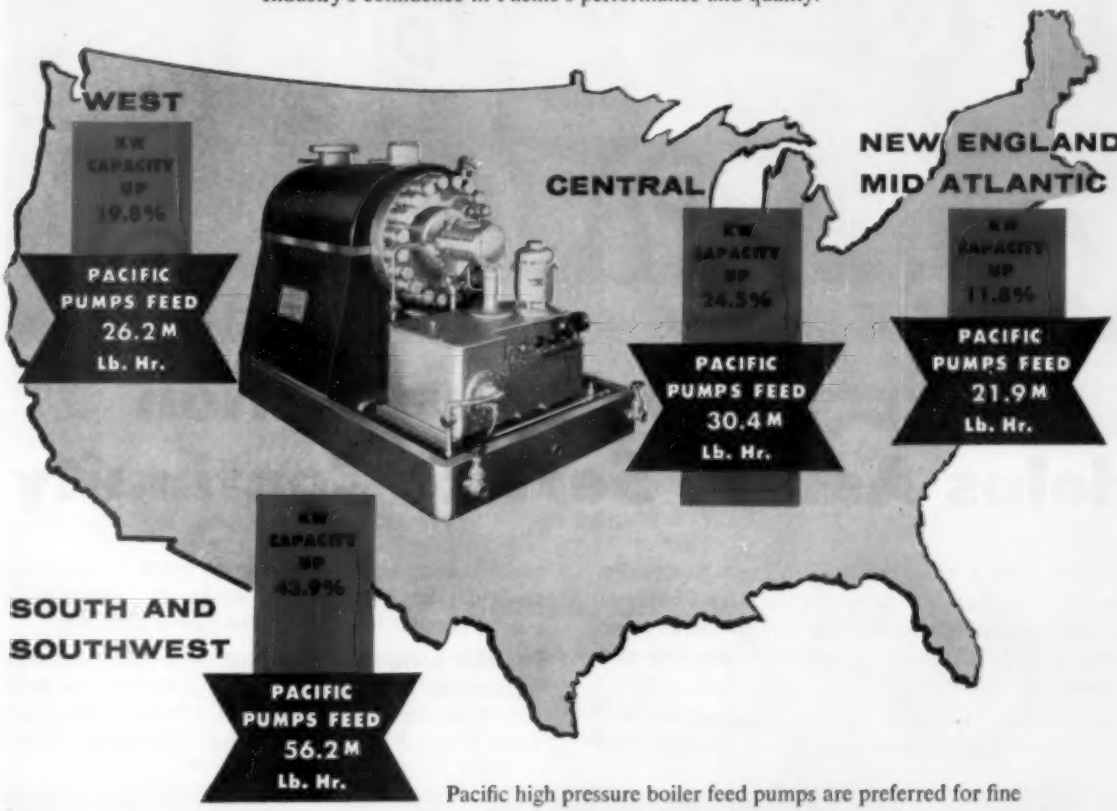
CUSTOMER SERVICE—A large, competent Richardson field-service organization . . . with an office near every installation . . . is another important reason to specify Richardson!

Keeping up with the kilowatts

From 1951 to 1955 the capacity of Pacific high pressure boiler feed pumps installed in each of the four regional areas of the U. S. has kept pace with the increase in electrical generating capacity in each area. This universal acceptance and repeat orders from individual Utilities in each area for 12-15 units express the Industry's confidence in Pacific's performance and quality.


WEST
KW CAPACITY UP 19.8%
PACIFIC PUMPS FEED 26.2 M Lb. Hr.
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PACIFIC PUMPS FEED 30.4 M Lb. Hr.
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PACIFIC PUMPS FEED 21.9 M Lb. Hr.
SOUTH AND SOUTHWEST
KW CAPACITY UP 43.9%
PACIFIC PUMPS FEED 56.2 M Lb. Hr.

Pacific high pressure boiler feed pumps are preferred for fine new power plants everywhere. They follow the load perfectly from 100% down to trip off. They are efficient—economical to operate and maintain.

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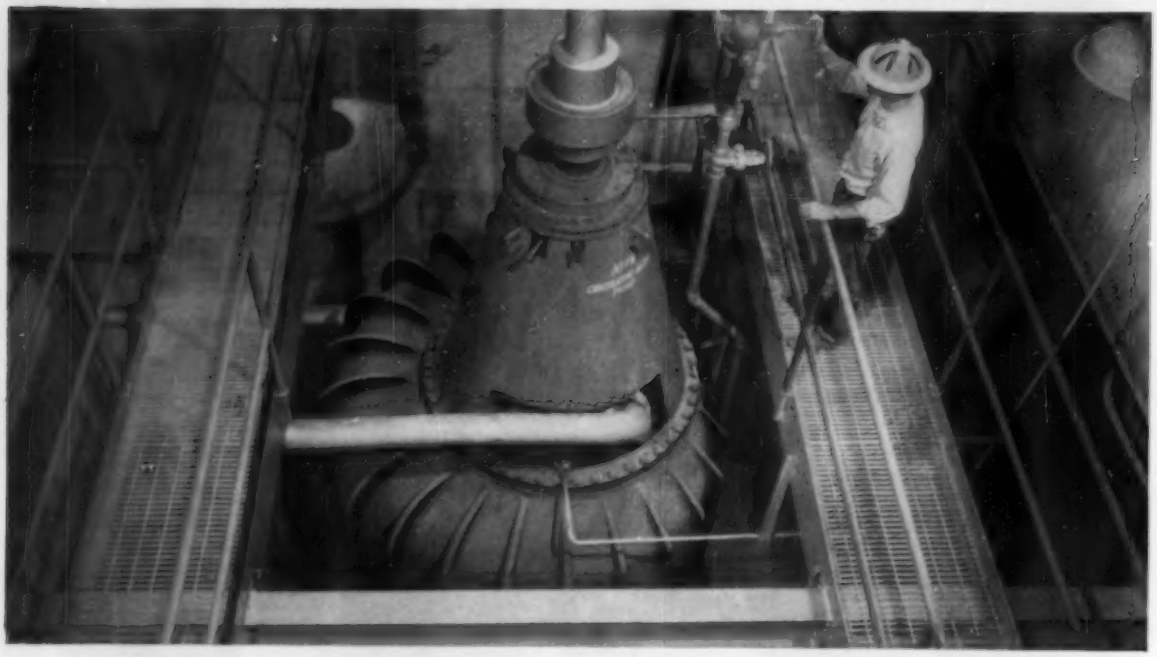
BF-22

Allis-Chalmers

PUMPS Meet Power Plant Requirements



Heavy-Duty Construction Helps Assure Service Continuity

At Clifty Creek Plant of the Indiana-Kentucky Electric Corporation, the use of 12 Allis-Chalmers vertical condenser circulating pumps for dry pit installation helps to assure service continuity and reduced maintenance.

Rigid whip-free shaft, protected oil-lubricated bearings, and special new-type rib construction that makes casing stronger and saves space — these are some of the features that make A-C circulating pumps popular throughout the power industry.

For the complete story on how Allis-Chalmers pumps can help you cut costs, contact your local Allis-Chalmers district office, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wis.

You get **MORE**... when you specify ALLIS-CHALMERS

Design and construction features like these assure dependable, day-after-day operation — better performance and low operating costs for you.

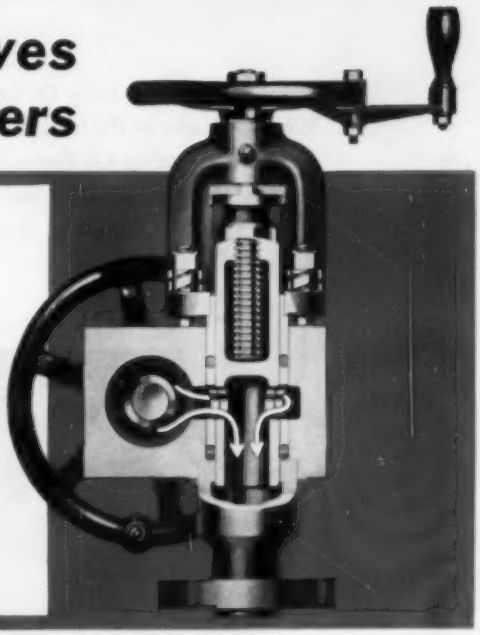
Benefit from Allis-Chalmers experience in building pumps for every industry. Industry-trained engineers are at your service to aid in selecting the right pump for your application. And, you can get the complete unit — pump, motor, control — from Allis-Chalmers.

ALLIS-CHALMERS

A-4973

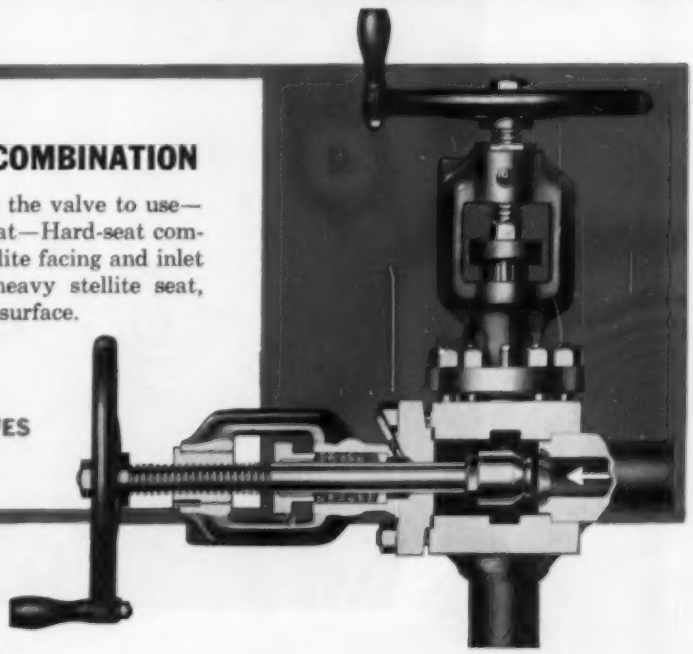
UNIT TANDEM

rugged blow-off valves for high pressure boilers



HARD-SEAT—SEATLESS COMBINATION

■ For boilers up to 1500 psi, this Yarway Unit Tandem Blow-Off Valve offers the maximum in dependable service. A one-piece forged steel block serves as the common body for the Yarway Stellite Hard-seat blowing valve and the Yarway Seatless sealing valve. All interconnecting flanges, bolts and gaskets are eliminated. The Unit Tandem at right is sectioned through Seatless Valve to show balanced sliding plunger in open position and free flow.



HARD-SEAT—HARD-SEAT COMBINATION

■ For boilers to 2500 psi, this is the valve to use—Yarway's Unit Tandem Hard-seat—Hard-seat combination. Disc has welded-in stellite facing and inlet nozzle has integral welded-in heavy stellite seat, providing smooth, hard-wearing surface.

OVER 4 OUT OF 5
HIGH PRESSURE PLANTS
USE YARWAY BLOW-OFF VALVES

Write for Yarway Catalog B-434

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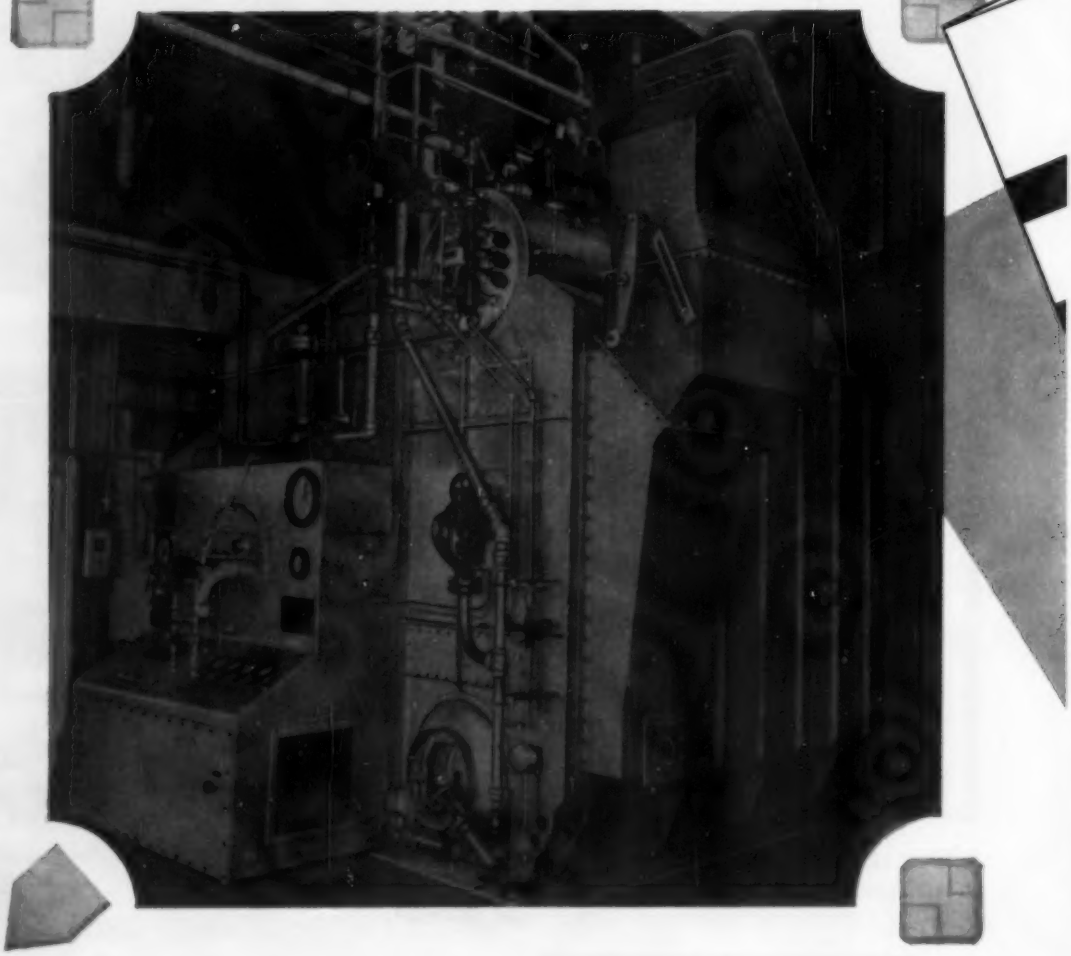
100 Mermaid Ave., Philadelphia 18, Pa.
BRANCH OFFICES IN PRINCIPAL CITIES

YARWAY BLOW-OFF VALVES

"You can't get a Better

Says Stanley D. Loomis, Chief Engineer of The United Piece Dye Works, a leader in the field of textile dyeing, finishing and printing. Of course, he's referring to the C-E Package Boiler, Type VP – installed in the newest and most modern United Piece Dye Mill at Charleston, South Carolina.

let's look at the box score for 1955 — -



Boiler Box Score"

SCORE CARD

AT BAT — 3 shifts a day, 6 days a week without a single unscheduled outage.

RUNS — around the clock with a quick response to load change and an ability to sustain a high overload capacity while producing high quality steam.

HITS — the performance mark. C-E's prompt service and complete cooperation matches the quality of the boiler.

PUT OUTS — of maintenance and repair bills are assured by the boiler's conservative design and built-in advantages. To date there have been no repair bills at all.

ASSISTS — in the continued full-production operation of the plant by meeting every steam need unfailingly.

Need a Package Boiler? See C-E! You can't get a better boiler box score.

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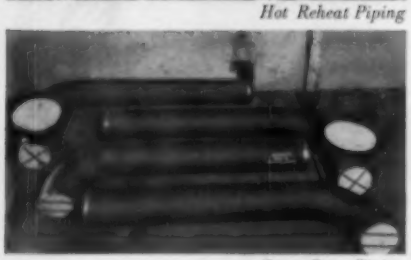
STEAM GENERATING UNITS • NUCLEAR REACTORS • PAPER MILL EQUIPMENT • PULVERIZERS
FLASH DRYING SYSTEMS • PRESSURE VESSELS
HOME HEATING AND COOLING UNITS • DOMESTIC WATER HEATERS • SOIL PIPE

Manual metallic-arc field welding. Electric coils, wound around areas adjacent to weld, are used in preheating, and in local stress relieving after completion of weld.

Main Steam Piping

Hot Reheat Piping



Cross-Over Piping

Shop fabricated assemblies above are produced to sizes which installation and shipping facilities permit.

FIELD ERECTION by P.P.&E.

Assures Safe, Efficient Operation of HIGH TEMPERATURE, HIGH PRESSURE PIPING

Pittsburgh Piping and Equipment Company was among the first to recognize the importance of complete piping fabricating service, including the responsibility for erection of the piping system.

At P.P.&E. sub-assembles are shop fabricated in sections as large as shipping facilities and installation area permits, are checked for dimensional alignment, and delivered ready for accurate erection. Field welds are planned for maximum accessibility. Consequently, erection by skilled, specially trained craftsmen is facilitated.

An experienced P.P.&E. field organization handles all erection problems, and coordinates field work with shop fabrication so that materials arrive on schedule, and in the sequence which permits erection to proceed rapidly and efficiently.

PRODUCTS AND SERVICES

Carbon Steel Piping	Forged Piping Materials
Cast Iron Fittings	Headers
Cast Steel Fittings	Manifolds
Chrome-Moly Piping	Pipe Bends
Copper Piping	Stainless Steel Piping
Corrugated Piping	Van Stoning
Creased Bends	Welded Assemblies
Expansion Bends	Welded Stainless Steel Tubing
Flanges	Welding Fittings

PP-15

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Washington	Wire Building

LET'S GO...with BRICK

Pack your bag, jump in your car, board your ship, your train, your plane—join America on the go. And thank brick that you *can* go. Refractory brick that produces the concrete for your highway, the turbines for your ocean liner, the stainless steel for your streamliner, the wings for your plane.

Everything that's made or that moves owes its existence to the fires of industry contained by valiant walls of refractory brick—refractories which withstand enormous heat for days, for weeks, for years.

How great the heat to be mastered? Where? When? How long? These are the concern of the refractory scientist, and it is the mission of General Refractories Company to meet the requirements.

To do this job, General Refractories maintains the world's greatest refractories laboratory, draws on resources the globe around for materials, and makes and distributes exactly the right refractory to industry, everywhere.

A Complete Refractories Service

GENERAL REFRACTORIES COMPANY

Philadelphia 2

GENERAL REFRACTORIES

A COMPLETE REFRACTORIES SERVICE FOR STEAM GENERATION

Monolithic furnace linings of GREFCO plastic firebrick are economical and will provide long uninterrupted service. Three high quality mixes are available for various furnace conditions with a selection of well engineered refractory and high temperature alloy metal anchors for various combinations and thicknesses.

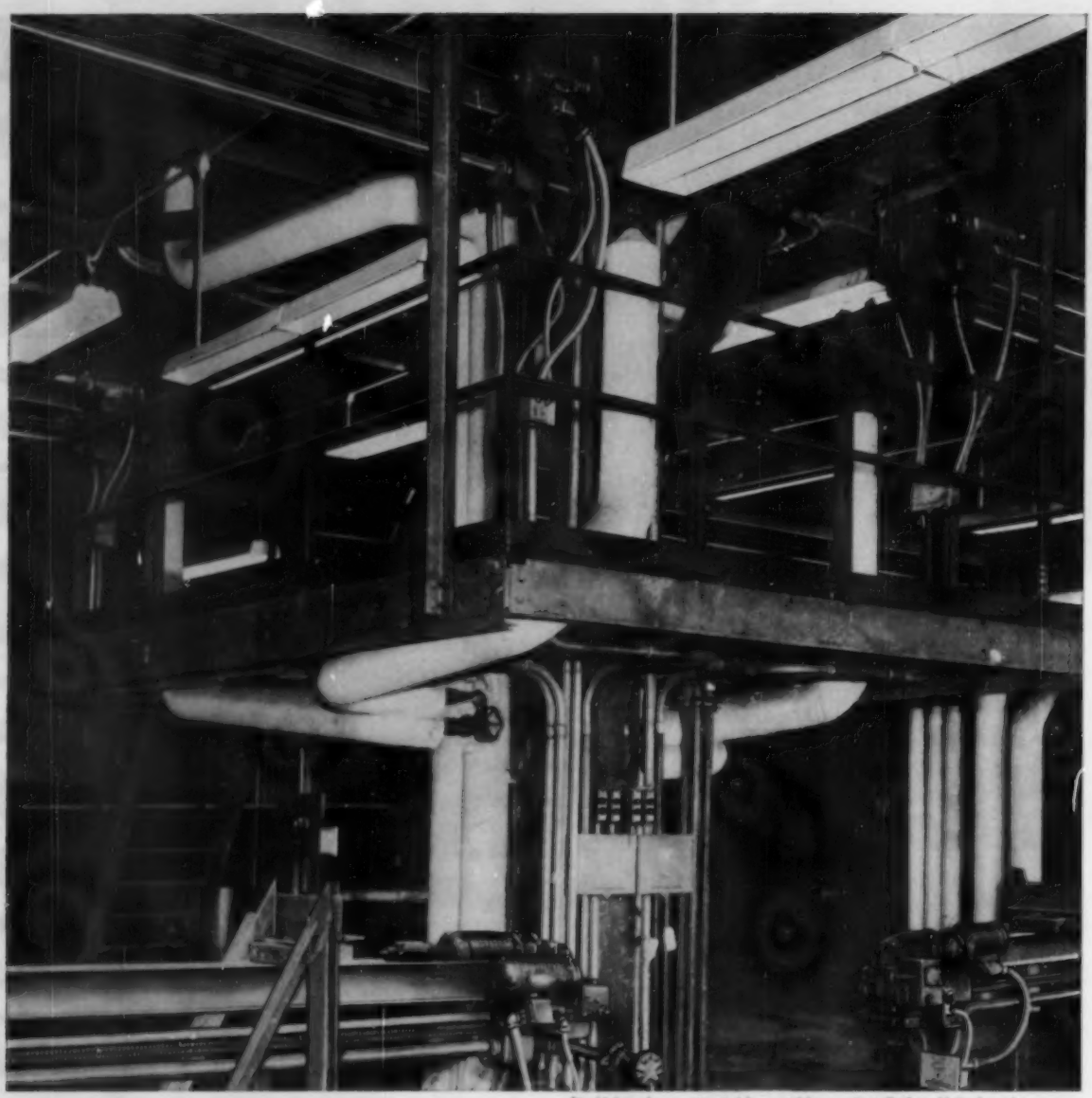
GREFCO plastics are manufactured at three strategically located plants in Pennsylvania, Missouri and Georgia. Stocks are maintained for prompt truck delivery at all company warehouses and dealers in principal cities.

When you specify GREFCO you are assured of quality second to none. The world's finest and best equipped refractory laboratory is constantly developing new products and improving old ones. District laboratories constantly check raw materials and finished products. GREFCO places great emphasis on uniform high quality.

SUPER BRIKRAM MIX-G—a super duty quality plastic firebrick with a special binder which provides an airset when material is air dried. Provides high strength throughout the entire thickness of the wall or arch.

SUPER BRIKRAM—a plastic firebrick of super duty quality for furnace linings where conditions warrant the use of super duty quality. Has excellent resistance to spalling and high temperatures.

BRIKRAM—a plastic firebrick of high duty quality. Excellent for patching or complete furnace linings where conditions do not require a super duty quality refractory.



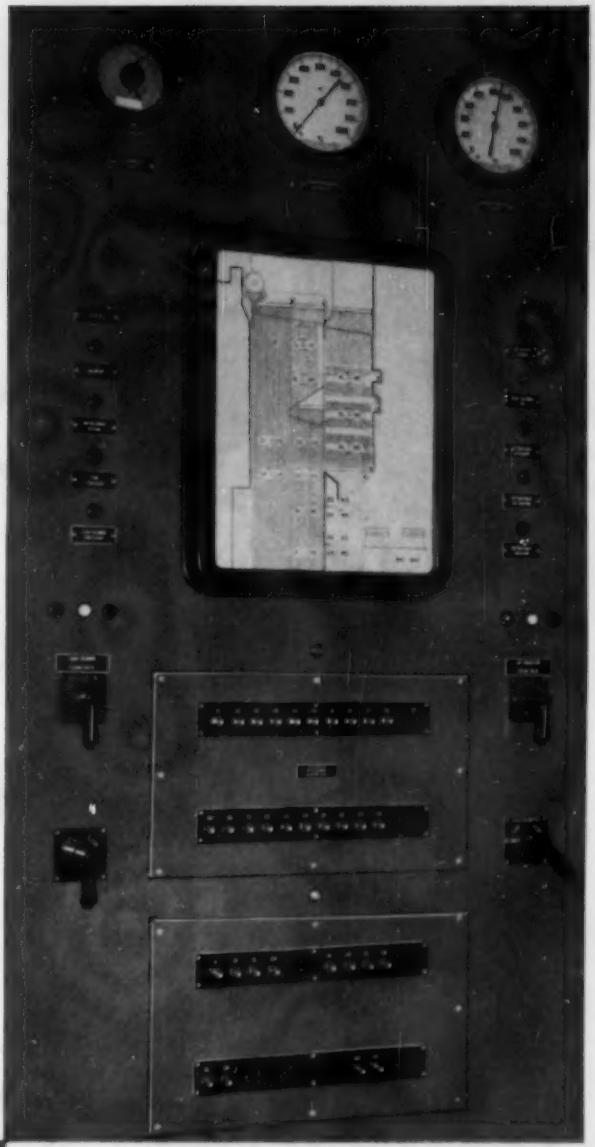
Six Vulcan long retractable soot blowers installed on Units 1 and 2. Vulcan long retracts have been built for travels over 35 feet. They can blow with steam or air without change in equipment.

Georgia Power Company installs VULCAN automatic-sequential soot blowing system

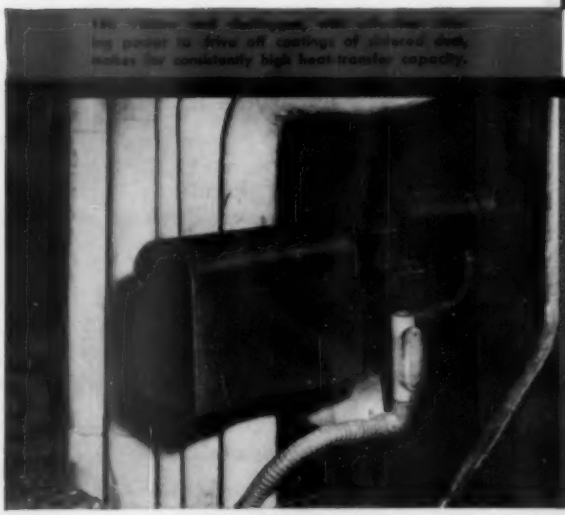
Keeping three Babcock & Wilcox reheat boilers effectively clean is a push-button operation at Georgia Power Company's Plant Hammond. That's because each boiler is equipped with Vulcan Automatic-Sequential Soot Blowing. The system includes both long retractable soot blowers and wall deslaggers.

The centralized control panel for each electrically-driven system is located in the main boiler control room. There the operator starts the cleaning sequence by simply pushing a button. He can see at a glance that each unit starts operation at the right time and pressure, blows for the proper period, and cuts out of service. If an individual blower requires more frequent or prolonged operation, manual control is right at his fingertips. With Vulcan, each boiler section is cleaned efficiently, automatically. No soot or slag accumulates to decrease operating efficiency.

No matter what size your boiler—whether it's power or process—you can increase operating efficiency and get low cost, effective cleaning with Vulcan Automatic-Sequential or Selective-Sequential Soot Blowing.



From this central control panel, the operator can check each step of the cleaning cycle; has choice of automatic or manual control.



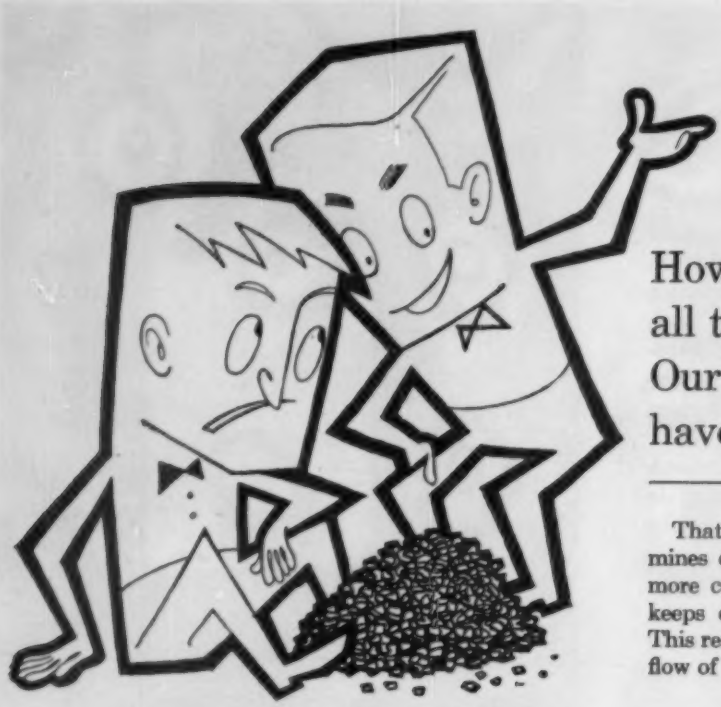
COPES-VULCAN DIVISION
ERIE 6, PENNSYLVANIA
BLAW-KNOX COMPANY

COPES VULCAN

50th Anniversary

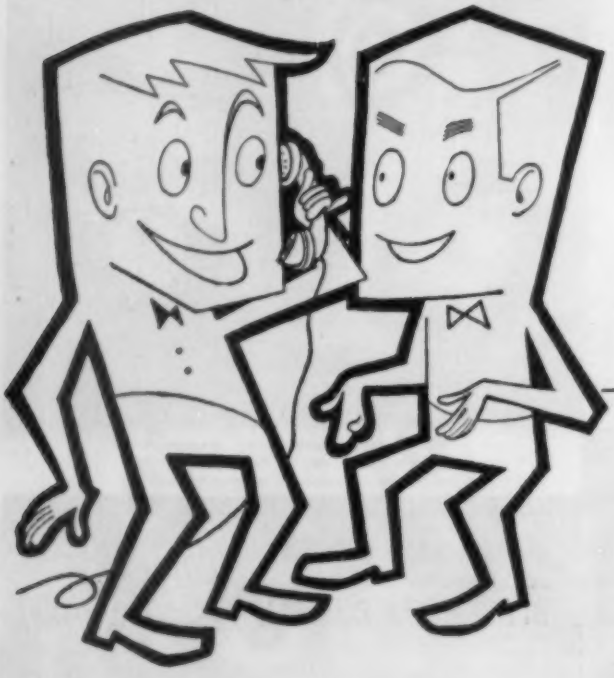
BLAW-KNOX

1906-1956



How come you can get all the coal you want? Our deliveries have been slow!

That's because we buy all our coal from mines on the Chesapeake & Ohio. C & O has more coal cars than any other railroad and keeps close to 99% of them in good order. This ready car supply means an uninterrupted flow of coal to consumers.



How about the coal? Is that as good as the service?

C & O territory has always been known for the superior quality coal it produces. And the C & O fuel service engineer is always ready to help us find exactly the right coal for our particular needs.

P.S.

There's a lot more to buying coal than the cost per million BTU. Why not contact coal producers on the C & O to solve your particular fuel requirements, or write to: R. C. Riedinger, General Coal Traffic Manager, Chesapeake & Ohio Railway Co., Terminal Tower, Cleveland 1, Ohio, for the assistance of a C & O fuel service engineer.

Chesapeake and Ohio Railway

WORLD'S LARGEST CARRIER OF BITUMINOUS COAL

Heavy-walled sections of new and existing alloys, most never before used for the purpose, are tested and evaluated by Kellogg toward improving design and performance of main and reheat steam piping.

M. W. KELLOGG METALLURGY KEEPS PACE

With wall thicknesses of main and reheat steam piping for current steam-electric power plants already approaching the upper limits of practicality, supercritical pressures and temperatures present a multiplicity of metallurgical problems to the power piping designer and fabricator. New and stronger stable alloys must be developed, new welding materials found, and new welding techniques and heat treating procedures perfected.

At The M. W. Kellogg Company, new materials containing alloying elements such as molybdenum, cobalt, tungsten, nitrogen, and titanium —in addition to chromium, nickel, and columbium—are now being investigated for long term high pressure service to 1300 deg. F. Most have never before been used for main or reheat steam piping. Heavy-walled sections of these materials are welded, tested, and evaluated by every known technique at Kellogg's Jersey City metallurgical laboratories.

The results of these continuing studies will prove extremely valuable to consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.

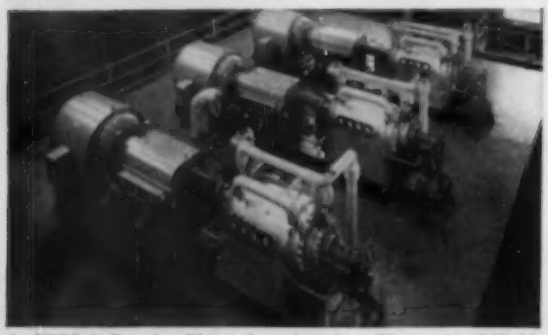
Sections of piping are welded, using various materials and techniques, and then tested for strength and other characteristics.

FABRICATED PRODUCTS DIVISION
THE M. W. KELLOGG COMPANY, 225 BROADWAY, NEW YORK 7, N.Y.
The Canadian Kellogg Company, Ltd., Toronto • Kellogg International Corp., London
SUBSIDIARIES OF PULLMAN INCORPORATED

POWER PIPING—THE VITAL LINK

Potomac Electric Power

The Potomac River Plant is one of three PEPCo electric-power giants serving Washington, D.C., and nearby areas of Maryland and Virginia.



At PEPCo's Benning Plant, three American Blower Gyrol Fluid Drives provide adjustable-speed control for boiler-feed pumps. Each is rated at 1250 hp at 3600 rpm. Six Gyrol Fluid Drives for the same application are installed at the Potomac River Plant — each is rated at 1750 hp at 3600 rpm.

American Blower Forced Draft Fans are also installed at the Potomac River Station. Fans on Boilers 1 and 2 are rated at 113,000 cfm @ 100°F @ 11.0" sp @ 1150 rpm. Fans on Boilers 3 and 4 are rated at 111,000 cfm @ 100°F @ 17.5" sp @ 700 rpm.

records all-time peak load:

810,000 kw

Potomac Electric Power Company's new high peak load of 810,000 kw in 1955 marked a 9.3% increase above the peak of the previous year. Although it was appreciable, the boost is only the beginning.

The coming years will see the continuation of an expansion program in which Potomac Electric Power Company has been engaged since the close of World War II . . . to better serve its more than 320,000 customers in the District of Columbia, and areas of Maryland and Virginia. During the 14-year period, 1947 to 1960, additions to PEPCo's electric plant are expected to total $320 million.

As an important part of its power build-up, PEPCo relies on American Blower Mechanical Draft Fans for efficient air handling and Gyrol Fluid Drives for smooth power transmission.

Like PEPCo, many other progressive utilities depend on American Blower equipment to meet rigid power-plant demands. Perhaps we can serve *you*, too. Call our nearby branch office for full data on our Mechanical Draft Equipment, Fly Ash Precipitators, Heavy Duty Steam Coils, and Gyrol Fluid Drives for boiler-feed pump and fan control.

American Blower Sirocco Induced Draft Fans service four boilers at the Potomac River station. Latest fans are rated at 160,000 cfm @ 250°F @ 18.0" sp. @ 667 rpm.

AMERICAN BLOWER CORPORATION, DETROIT 32, MICHIGAN • CANADIAN SIROCCO COMPANY, LTD., WINDSOR, ONTARIO

Division of American-Standard

AMERICAN 75th ANNIVERSARY YEAR **BLOWER**

air preheater installations are Ljungstrom®

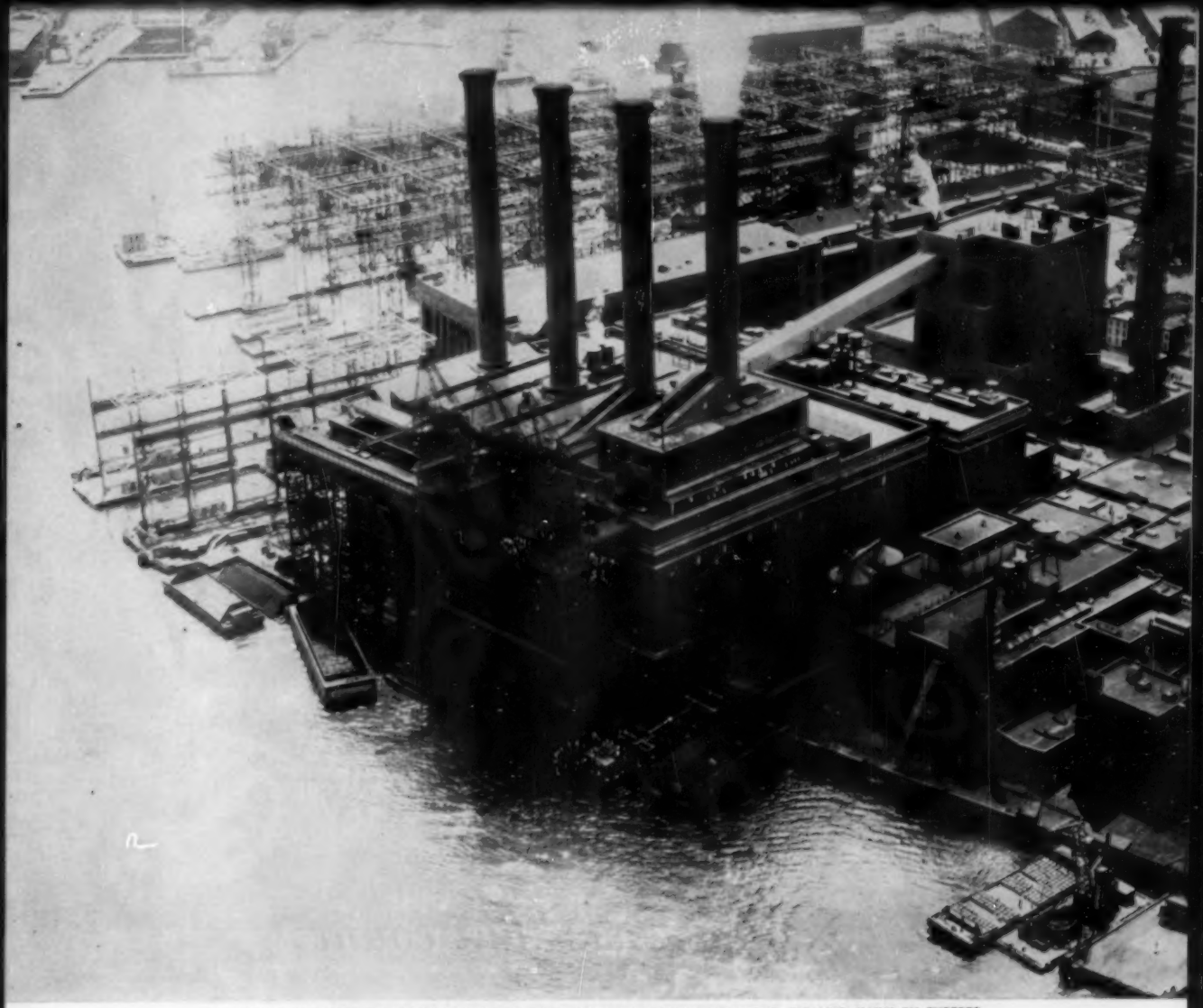
Advantages of the Ljungstrom Air Preheater

- Size for size, recovers more heat than any other type.
- Reduces fuel consumption. Permits use of lower-grade fuels. Increases boiler output and reliability.
- Eliminates cold spots...keeps corrosion to a minimum.
- Easier, faster to clean and maintain.
- Requires far less supporting steel and is quickly erected.

MINIMUM CORROSION is an important reason. There are no cold spots in a Ljungstrom. Temperature is uniform on all heating surfaces—corrosion-causing condensation is reduced.

For all the facts, send now for a free copy of our 38-page manual.

The Air Preheater Corporation 60 East 42nd Street, New York 17, N. Y.



FOR LONG LIFE AND TOP EFFICIENCY THE EQUIPMENT IN THIS POWER PLANT IS CLEANED ONLY BY EXPERTS.

IT'S NOT WORTH THE CHANCE —CLEAN IT RIGHT

Equipment that operates at less than peak efficiency eats into your company profits. Chemical cleaning can help stop these losses—but only when it's done by experts. Unless you rely on experts, you're taking a chance with your men and valuable equipment.

Dowell engineers understand your cleaning problems and they have the *experience* needed to solve them. Thoroughly trained, they're backed by Dowell's 15 years' experience in removing troublesome scale deposits from virtually every kind of equipment in every kind of industry. They're aided, too, by a completely modern, fully staffed and excellently equipped *research* laboratory.

But, expert cleaning goes beyond keeping your equipment in top condition. Dowell considers the safety of company personnel at every step of the operation. The safest possible working procedures are worked out with your safety personnel.

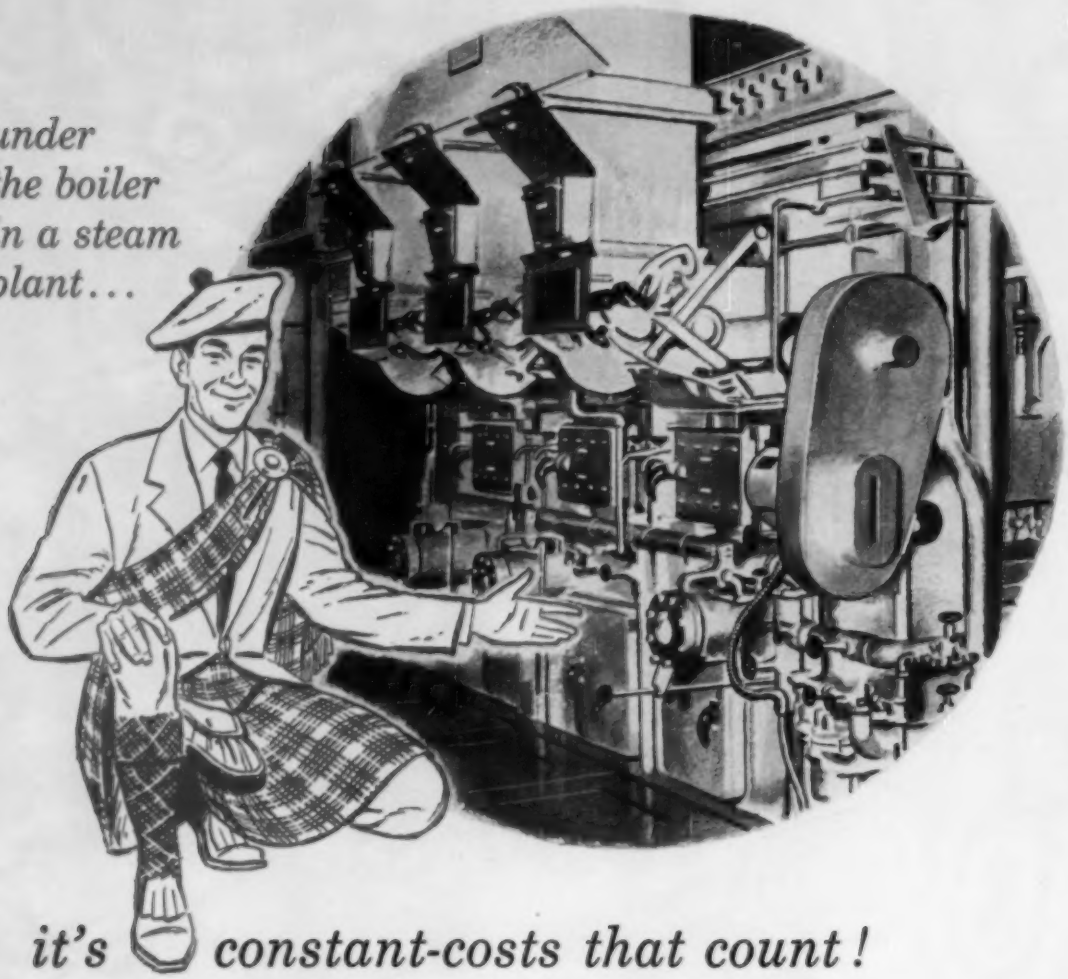
Call Dowell. Our engineers are always ready to discuss chemical cleaning problems with you. There's no obligation. Or write Dowell Incorporated, Tulsa 1, Okla., Dept. D-25.

chemical cleaning service for industry

DOWELL

A SERVICE SUBSIDIARY OF THE DOW CHEMICAL COMPANY

under the boiler in a steam plant...



it's constant-costs that count!

Be Thrifty! Expensive boiler installations designed to burn fuels with limited futures is doubtful wisdom. The sensible alternative is to *bank on Bituminous!* Plotting your costs over the long run will prove efficiency and lowest cost in most cases. For, Bituminous reserves are unlimited—they're nearest to most manufacturers—coal technology improves burning equipment, efficiency and cost year by year.

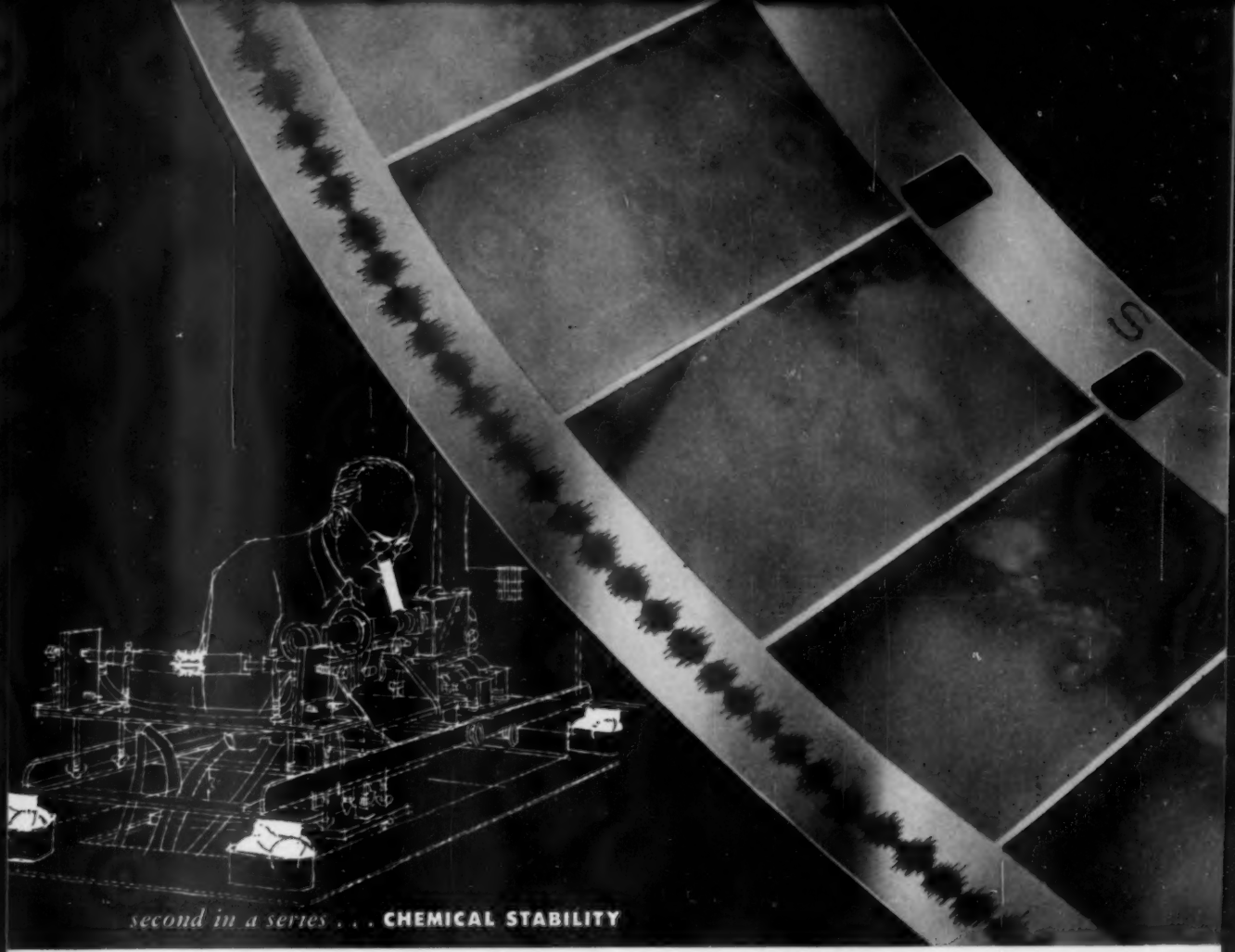
Let our Coal Technical Service plot a constant-low-cost Bituminous coal for your needs. *Ask our man!*

COAL TRAFFIC DEPARTMENT, BALTIMORE & OHIO RAILROAD

Baltimore 1, Maryland—Phone: LExington 9-0400

BALTIMORE & OHIO RAILROAD

BITUMINOUS COALS FOR EVERY PURPOSE



second in a series . . . **CHEMICAL STABILITY**

Comparative stability of MONOFRAX® fused cast refractory (left) vs. fireclay (right) . . . under attack by molten glass, as viewed through the high temperature microscope — one of Carborundum's most useful test facilities. (16 mm. frames shown are not consecutive.)

Unusual Properties of Refractory Materials

Chemical stability — Even under high temperature attack by gases, acids, corrosive solutions, molten salts and molten metals — the chemical stability of CARBORUNDUM'S super refractories enables them to fill industrial requirements that other refractories are unable to meet. For this reason, they are being used with increasing frequency in critical applications: i.e. as linings in controlled-atmosphere furnaces, in the production of muriatic acid, as radiant tubes, in the submerged combustion of liquids containing free acid — such as mixed chlorides and sulphates of iron, zinc, mercury and tin; in retorts for reducing and refining zinc, melting copper alloys and for hundreds of similar applications.

CARBORUNDUM'S laboratories are constantly developing new super refractories to meet specialized application problems. Current research projects include refractory materials for guided missile components, for atomic reactors, and for applications where wear and corrosion are unusually severe.

The forthcoming issue of CARBORUNDUM'S new magazine "Refractories" treats the subject "Chemical Stability of Refractories" in detail. Send for your copy today.

CARBORUNDUM

Registered Trade Mark

VALUABLE INFORMATION FOR USERS OF:

REFRACTORIES • CASTABLE CEMENTS • POROUS PLATES AND TUBES • CATALYST SUPPORTS • OXIDE, BORIDE, NITRIDE AND CARBIDE HIGH-TEMPERATURE MATERIALS • CERAMIC FIBER

All in the new magazine "Refractories"

MAIL THIS COUPON TODAY

Dept. E46 Refractories Division
The Carborundum Company, Perth Amboy, N. J.
Please send me the forthcoming issue of "Refractories".

Name _____ Title _____

Company _____

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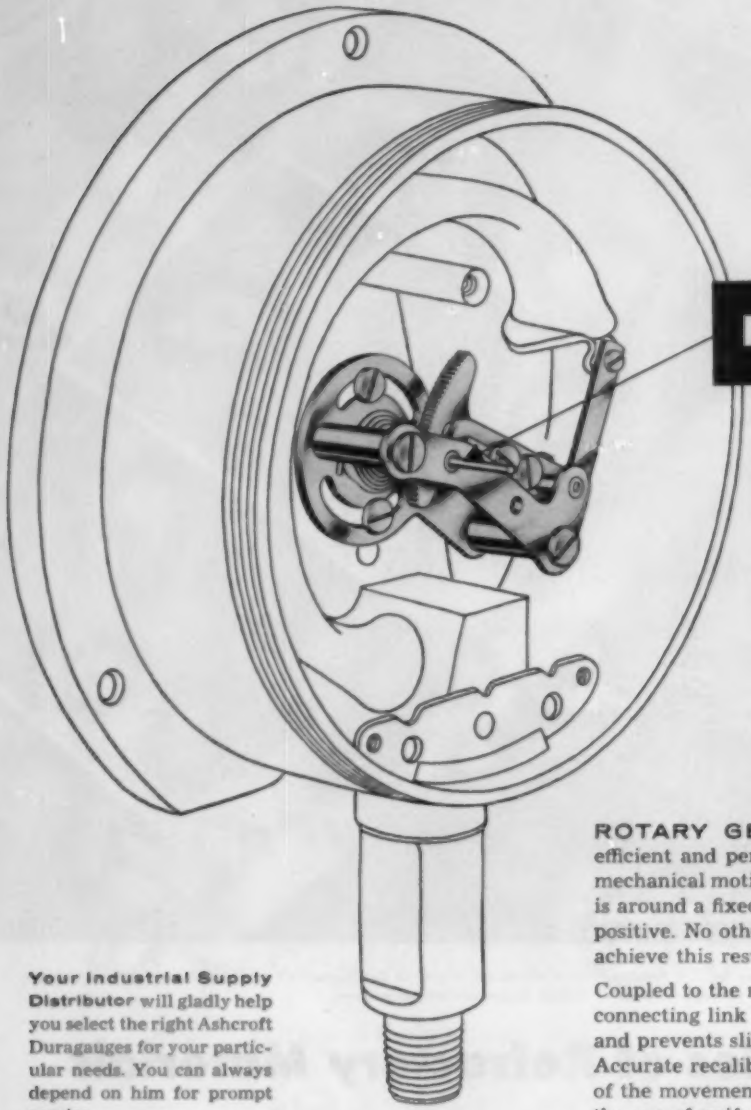


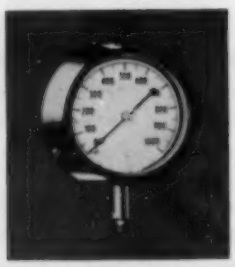
Why does the MOVEMENT in the ASHCROFT DURAGAUGE outperform all other types?

ROTARY GEARED MOTION, the most efficient and perfect method of transmitting mechanical motion ever developed. Because rotation is around a fixed center, pointer position is always positive. No other type of movement can ever achieve this result.

Coupled to the movement is a one-piece connecting link that guarantees correct calibration and prevents slippage or parting under tension. Accurate recalibration is easy from front or rear of the movement. Universal adjustability permits the use of uniformly graduated dials, thereby facilitating maintenance.

The Ashcroft Duragauge is available with all-stainless-steel movement or stainless steel with nylon bearings and pinion gear. There are case designs and materials, Bourdon tube materials, pressure ranges and dial sizes to meet your service conditions exactly. Save time, trouble and money. Specify the pressure gauges of highest sustained accuracy and durability – Ashcroft Duragauges.

Your Industrial Supply Distributor will gladly help you select the right Ashcroft Duragauges for your particular needs. You can always depend on him for prompt service.

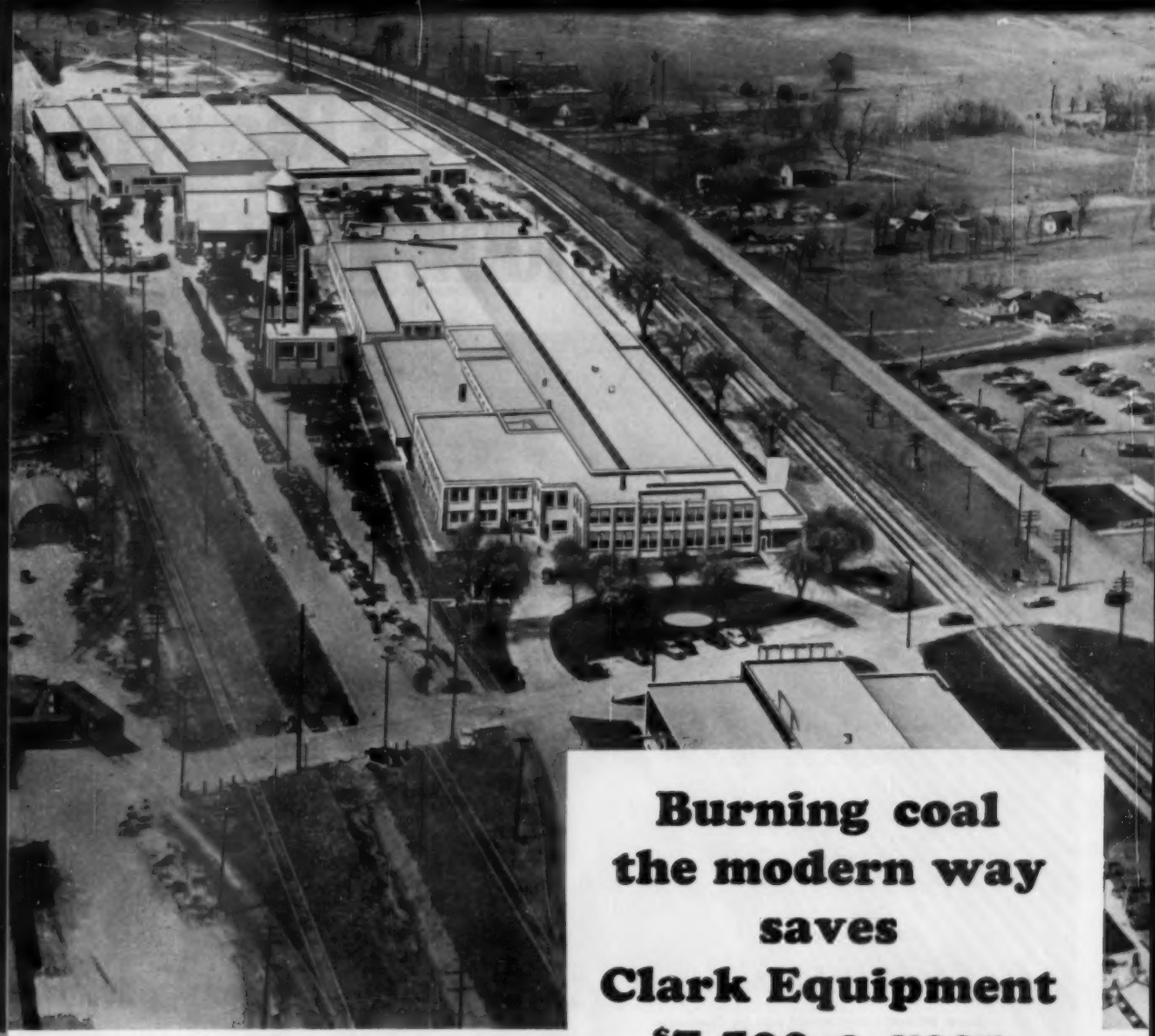


In Canada: *Manning, Maxwell & Moore of Canada, Ltd., Galt, Ontario*

ASHCROFT GAUGES

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONNECTICUT

MAKERS OF 'AMERICAN' INDUSTRIAL INSTRUMENTS, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN-MICROSEN' INDUSTRIAL ELECTRONIC INSTRUMENTS, *Stratford, Conn.* 'HANCOCK' VALVES, *Watertown, Mass.* 'CONSOLIDATED' SAFETY RELIEF VALVES, *Tulsa, Oklahoma.* AIRCRAFT CONTROL PRODUCTS, *Danbury & Stratford, Conn. and Inglewood, Calif.* "SHAW-BOX" AND 'LOAD LIFTER' CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES, *Muskegon, Mich.*



Burning coal the modern way saves Clark Equipment $7,500 a year

Consult an engineering firm

Designing and building hundreds of heating and power installations a year, qualified engineering firms can bring you the latest knowledge of fuel costs and equipment. If you are planning the construction of new heating or power facilities—or the remodeling of an existing installation—one of these concerns will work closely with your own engineering department to effect substantial savings not only in efficiency but in fuel economy over the years.

facts you should know about coal

In most industrial areas, bituminous coal is the lowest-cost fuel available • Up-to-date coal burning equipment can give you 10% to 40% more steam per dollar • Automatic coal and ash handling systems can cut your labor cost to a minimum. Coal is the safest fuel to store and use • No smoke or dust problems when coal is burned with modern equipment • Between America's vast coal reserves and mechanized coal production methods, you can count on coal being plentiful and its price remaining stable.

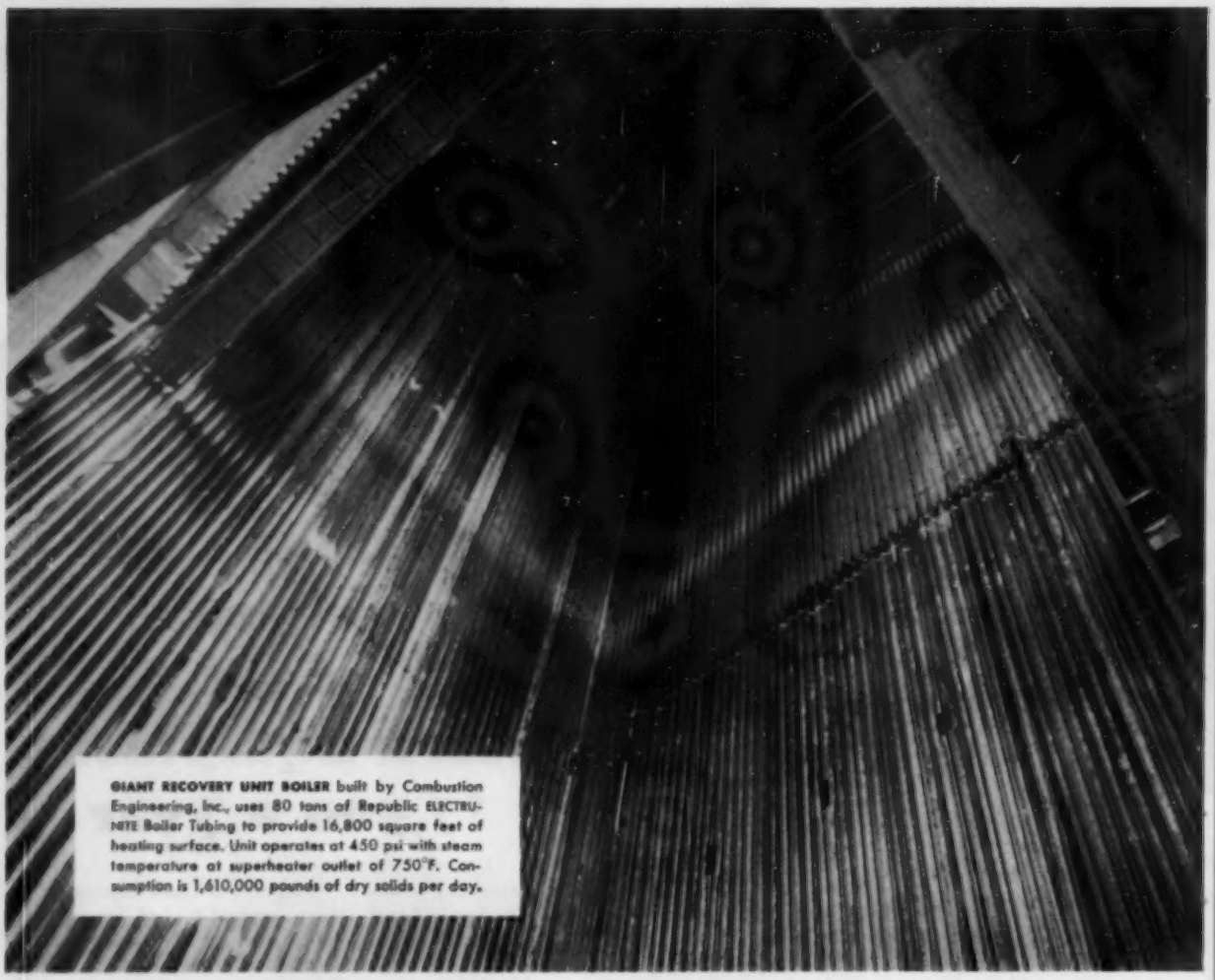
Expanding production facilities at Clark Equipment Co., Battle Creek, Mich., created a need for more steam within the plant. In the face of rising overall costs, Clark engineers decided to meet this demand by modernizing the firm's power system.

Today, two watertube boilers utilizing spreader stokers have replaced three firetube boilers, underfeed fired. Stokers are fed by screw conveyor and controls are fully automatic. As a result of these and other aspects of its modernization program, Clark's boiler plant has now increased plant efficiency, supplying reliable, low-cost steam for all purposes—at a savings of $7,500 a year.

For further information or additional case histories showing how other plants have saved money burning coal, write to the address below.

NATIONAL COAL ASSOCIATION
Southern Building • Washington 5, D.C.

Furnace Tubing for C-E Recovery in pulp mill is 100% REPUBLIC



GIANT RECOVERY UNIT BOILER built by Combustion Engineering, Inc., uses 80 tons of Republic ELECTRUNITE Boiler Tubing to provide 16,800 square feet of heating surface. Unit operates at 450 psi with steam temperature at superheater outlet of 750°F. Consumption is 1,610,000 pounds of dry solids per day.

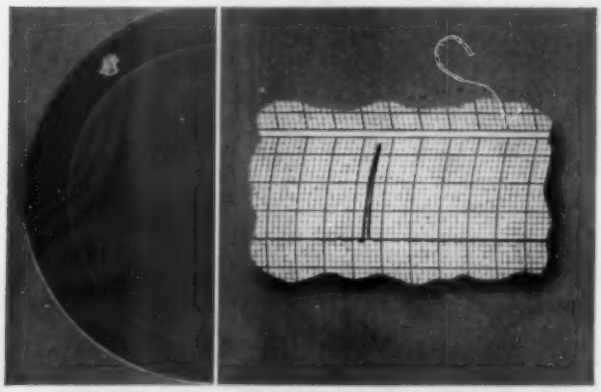
REPUBLIC

REPUBLIC STEEL

World's Widest Range of Standard Steels

Unit ELECTRUNITE

UNIFORM DUCTILITY OF ELECTRUNITE Boiler Tubing helps rolling-in. Tube ends are easily and securely rolled into tube holes in drum. Result: consistently tight, weeper-free joints plus maximum ease of installation.



HERE'S THE ULTIMATE IN TUBE PROTECTION. FARROWTEST®, an electronic method of checking tubing for injurious defects, is exclusive with Republic. The oscillograph (shown above) records a defect registered on the macrograph. The presence of the defect passing through the FARROWTEST equipment automatically stops the machine, allowing the operator to mark and reject the tube. Send coupon for details.

Eighty tons, approximately 24,000 linear feet of Republic ELECTRUNITE® Boiler Tubing went into the boiler of one of the nation's largest C-E Recovery Units, recently installed for one of the South's largest pulp and paper plants.

Designed and built by Combustion Engineering, Inc., New York, the giant unit has a twofold purpose: to recover chemicals from spent liquor in the pulp mill; and to produce as much steam as possible from the boiler portion of the unit, using solids taken from the liquor as fuel. Since these functions are vital to both operation of the pulp mill and disposal of spent liquor, dependability and efficiency of the boiler are of paramount importance.

And that's where ELECTRUNITE excells.

ELECTRUNITE Boiler Tubes have a world-wide reputation for efficiency and reliability. The electric welding process, by nature, produces precise, uniform wall thickness assuring uniform, efficient heat transfer all around and throughout the length of each tube. Dependability cannot be threatened by longitudinal thin spots. Further, all ELECTRUNITE Tubes are hydrostatically or electrically tested to make certain of maximum performance in each length in any quantity.

Get all the facts on ELECTRUNITE Boiler, Condenser and Heat Exchanger Tubing from your local Republic Representative. Meantime, mail the coupon for your free copy of our handy wall chart entitled, "Care and Maintenance of Boiler Tubing." It's a handy guide to protecting your boiler installation from corrosion, erosion and physical wear and tear. Do it today.

REPUBLIC STEEL CORPORATION
Dept. C-1707
3172 East 45th Street, Cleveland 27, Ohio

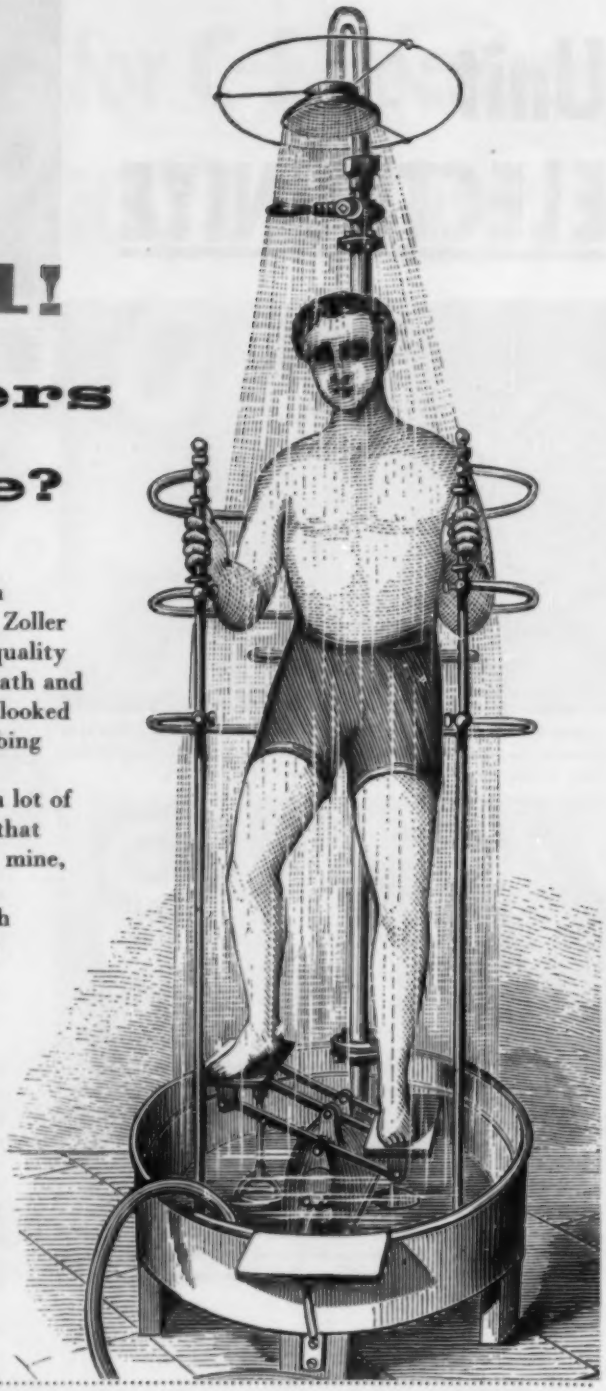
Please send:
- ☐ Illustrated booklet giving facts on ELECTRUNITE Boiler Tubes
- ☐ 8-page brochure on Heat Exchanger Tubing—carbon steel ☐ stainless steel ☐
- ☐ Handy wall chart on Care and Maintenance of Boiler Tubes
- ☐ Data on exclusive FARROWTEST

Name_____ Title_____
Firm_____
Address_____
City_____ Zone____ State_____

STEEL
and Steel Products

Egad!

will wonders never cease?



Patented! Warranted! A marvel of modern ingenuity! Yes, back in 1886, when Bell & Zoller first started marketing their famous high-quality coals, this combination leg-pump shower bath and morning workout was all the rage—and it looked like the new-fangled fad of "indoor" plumbing was here to stay!

Yes, we've come a long way, and made a lot of changes since then. But there's one thing that hasn't changed. 70 years ago we set out to mine, process and deliver the best possible selection of free-burning, high-heat, low-ash coals—by the best, low cost, most modern methods available.

And we're still doing that job in 1956!

* * *

You know these coals by the famous brand names of ZEIGLER, MOSS HILL, ORIOLE, MURDOCK, LIBERTY SMOKELESS, BUCKHORN... and you can be sure of fast, low cost delivery through your nearest Bell & Zoller office—today!

Bell & Zoller Coal Company

70 YEARS OF SERVICE TO COAL USERS

BELL BUILDING, CHICAGO 1, ILLINOIS

Detroit • New York • St. Louis • Minneapolis
Omaha • Milwaukee • Louisville • Washington, D.C.
Terre Haute, Ind. • Mount Hope, W.Va.

DE LAVAL OPPELLER PUMPS

last longer... cut maintenance costs

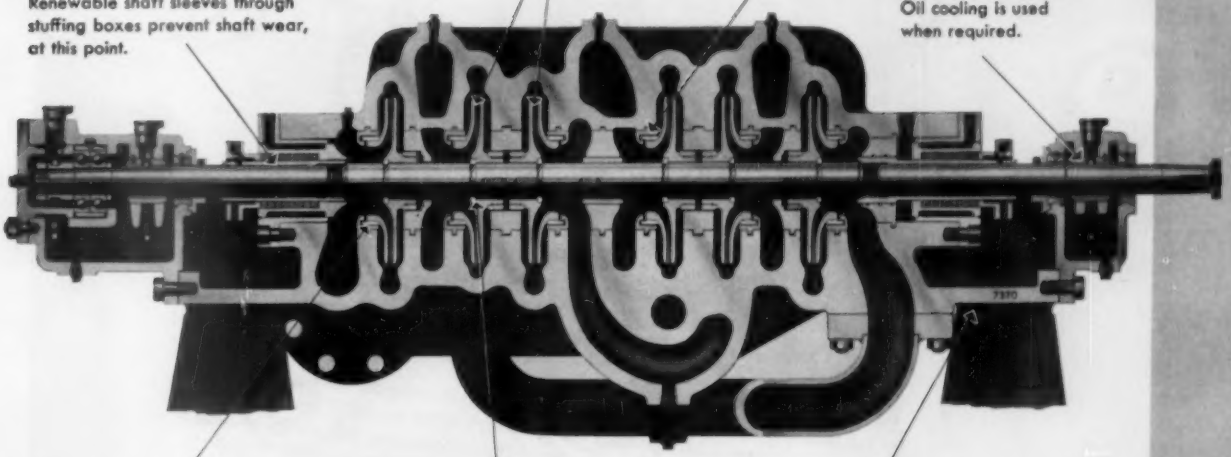
Stages are arranged to reduce differential pressures between stages. This insures permanent sealing at the casing-joint and at interstage diaphragms.

Pairs of back-to-back impellers balance axial thrust. One-purpose thrust bearing carries no radial load, maintains axial alignment.

Labyrinth wearing rings permit safe clearances and reduce wear.

All bearings are ring-oiled, sealed against contamination by water or dust. Oil cooling is used when required.

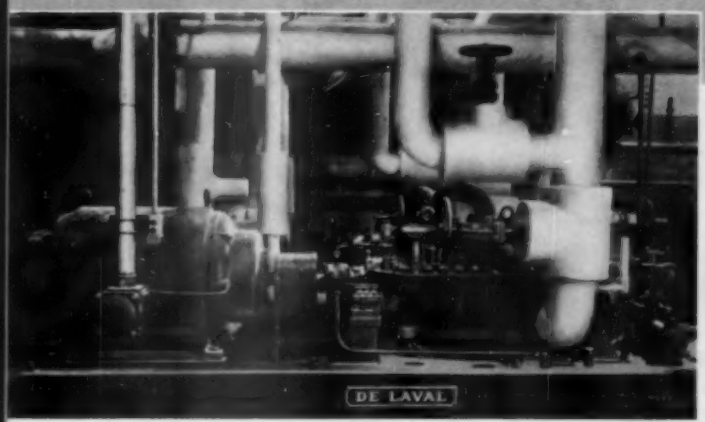
Renewable shaft sleeves through stuffing boxes prevent shaft wear, at this point.



Threaded impeller wearing rings make replacement easy without heating or damage to impellers.

Individual impeller mountings, with split locating rings, make interstage shaft sleeves unnecessary. Impellers can't shift with shaft expansion and contraction.

Casing support insures coupling alignment at any operating temperature.



Here are two De Laval 6-stage Oppeller Pumps used for boiler feed service in an industrial installation.

The design features above show clearly why De Laval Oppeller Pumps stay on the line longer and cost less to maintain. These pumps are used for boiler feed, hydraulic systems, descaling spray, mine dewatering, refinery oil pumping and similar services.

De Laval Oppeller Pumps are available in sizes from 2 to 4 inches and 2 to 8 stages; capacities to 1000 gpm, pressures to 1200 psig and temperatures to 350 F.

DE LAVAL *Oppeller Pumps*

DE LAVAL STEAM TURBINE COMPANY

886 Nottingham Way, Trenton 2, New Jersey

DL286

NOW... greater piping loads, longer travels, with less headroom

The Grinnell Model R Constant-Support Pipe Hanger is available now in an *extended range* of sizes to provide completely overlapping coverage of loads from 47 lbs. to 32,267 lbs., and with travels up to 12 inches. New design modifications permit these hangers to be installed with a minimum of headroom, ranging from 29 inches (rod take-out) for the largest size — down to 10¾ inches for the smallest size.

The Model R provides constant support which is mathematically perfect for all positions of travel. This constancy of support is maintained throughout the full range of field adjustability. Needle bearings minimize friction.

Grinnell Constant-Supports are individually calibrated to support the exact load specified. All Model R Constant-Supports have a full 70 percentage points of field adjustability built into them. No less than 10% of this adjustability is allowed either side of calibration for plus or minus change in load. Field re-adjustments are easily made by turning a single load adjustment bolt.

Grinnell designs, manufactures, and distributes a complete line of pipe hangers and supports for every piping requirement. Grinnell maintains an experienced staff of engineers in the field — ready to assist you on the job with any piping problem.

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pipe and tube fittings • welding fittings • engineered pipe hangers and supports • Thermolier unit heaters • valves
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ONE APPLICATION OF *Easy-to-use* Nalco H-174 KEEPS YOUR FACILITIES

WEED FREE *all year long!*

Putting down one, low-dosage Nalco H-174 Weed Killer application *now* controls *all* vegetation, all year! Nalco-174 is easy to apply, too... Dry, dust-free granules need no mixing or dilution... Spread it as you would fertilizer or seed... Or directly from the convenient shaker box. But don't take it home! Nalco H-174 is an *industrial* herbicide... so powerful it kills *all* vegetation, even trees!

Killing action of Nalco H-174 is at the roots. Retention in soil prevents emergence, stops re-growth, kills seedlings and late-season weeds as soon as they put out roots.

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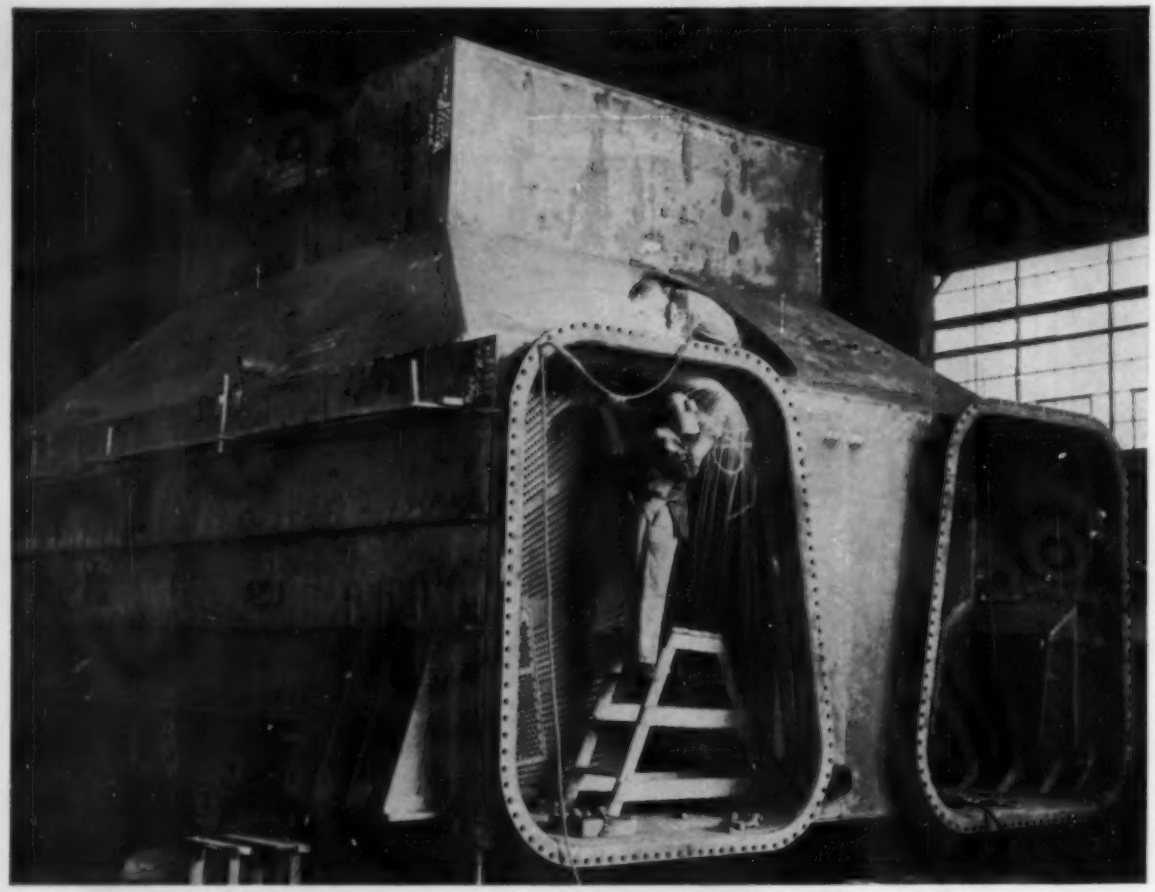

this surface condenser was specially designed to save space

Pictured above in the final stages of construction is a surface condenser designed by Lummus to save much-needed space at the White River Station of the Indianapolis Power & Light Company. The rectangular shape permits low headroom installation. Bayonetting a low pressure stage heater in the dome saves even more space.

This condenser, about to be placed in operation as unit #6 at the White River Station, has a total of 50,000 sq. ft. of tube surface, and was furnished complete with circulating water and condensate pumps and drivers, and a Lummus-designed air ejector unit.

Lummus was highly commended by Gibbs and Hill Inc.—the consulting engineers—and by the customer for efficient handling of engineering details, and for the workmanship which went into the building of the condenser in the Lummus plant. Lummus has been retained to build a second, duplicate unit at Indianapolis' Harding Street Station.

By working closely with consultants and the customer, Lummus engineers were able to solve a knotty space problem frequently encountered in power station design. These same men would be pleased to work with you on similar problems. Call on them.

THE LUMMUS COMPANY, 385 Madison Avenue, New York 17, New York. *Engineering and Sales Offices:* New York, Houston, Montreal, London, Paris, The Hague, Bombay. *Sales Offices:* Chicago, Caracas. *Heat Exchanger Plant:* Honesdale, Pa. *Fabricated Piping Plant:* East Chicago, Ind.

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Edward checks are competitively priced yet we get many "extras."
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Equalizer aids disk-piston lift, reduces wear and extends life of guiding surfaces. This rotation checks seat tightly and helps non-slam characteristics.

Here is a really dependable Pressure-Seal gasket — seals over a much wider area. Edward inlays body for excellent gasket surface.

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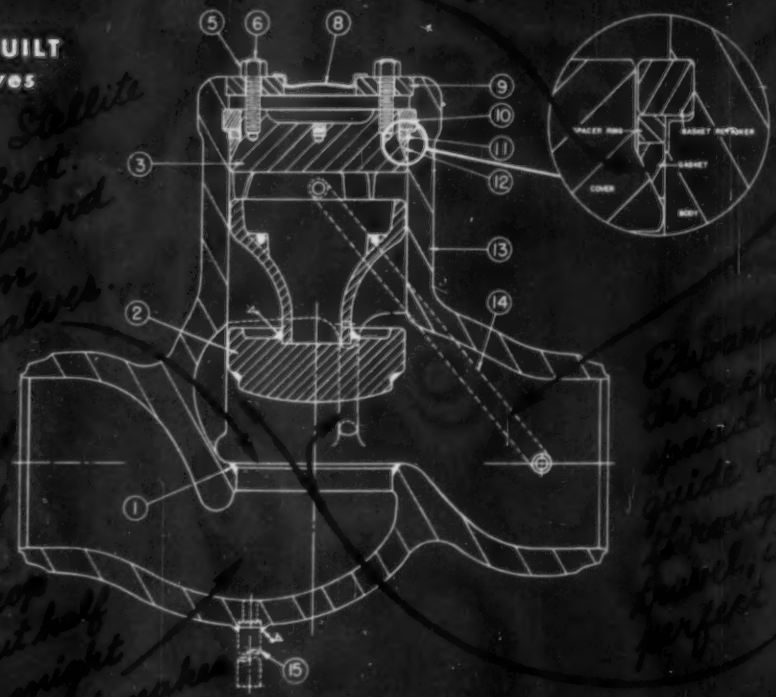
Edward Valves

Integral Stellite seat is best. Only Edward has it on large valves.

Streamlined body really helps. Pressure drop is only about half what you might guess. Edward makes streamlined angle check valves too.



Edward uses three equally spaced ribs to guide disk throughout travel, insuring perfect seating.

Let's have Edward quote on the checks as well as all steel valves on our next job.

LIST OF MATERIAL
QUANTITIES ARE FOR ONE VALVE
WHERE A.S.T.M. SPECIFICATIONS ARE INDICATED THE LATEST REVISION APPLIES

PIECE NO.	NAME OF PIECE	NO. REQ'D	MATERIAL	SPECIFICATIONS	EDWARD MTL. NO.
1	SEAT	1	INTEGRAL WITH BODY	STELLITED	601
2	DISK	1	FORGED ALLOY STEEL WITH STELLITED SEATING FACE	A.S.T.M. A182 GRADE F11 WITH CO-CR-W-FE DEPOSIT MIN. 1/8"	221
	PISTON WELDED TO DISK		CAST STEEL	A.S.T.M. A216 GRADE WCB	101
3	PRESSURE SEAL COVER	1	CAST STEEL C-0.25% MAX	A.S.T.M. A217 GRADE WC1	209
5	COVER STUD NUTS		STEEL	A.S.T.M. A194 GRADE 2H	27
6	COVER RETAINER STUDS		ALLOY STEEL	A.S.T.M. A193 GRADE B7	598
8	COVER RETAINER COVER	1	STEEL		
9	COVER RETAINER	1	STEEL PLATE	A.S.T.M. A285 GRADE B	119
10	GASKET RETAINER	1	EQUALIZER	A.S.T.M. A182 GRADE F6	812
11	SPACER RING	1	STEEL		
12	PRESSURE SEAL GASKET	1	ARMCO IRON-90 BHN MAX.	NICKEL PLATED	506
13	BODY	1	CAST STEEL C-0.30% MAX	A.S.T.M. A216 GRADE WCB	102
			CAST STEEL C-0.25% MAX	A.S.T.M. A217 GRADE WC6	226
			CAST STEEL C-0.20% MAX	A.S.T.M. A217 GRADE WC9	240
14	EQUALIZER	1	CHROME MOLYBDENUM	SCHEDULE 160 PIPE	229
15	DRAIN NIPPLE	1	CHROME MOLYBDENUM	SCHEDULE 160 PIPE	229

EDWARD VALVES, INC.
SUBSIDIARY OF ROCKWELL MANUFACTURING CO.
EAST CHICAGO, INDIANA

EDWARD PRESSURE SEAL
CAST STEEL HORIZONTAL CHECK VALVE
GENERAL ASSEMBLY

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Edward builds Globe and Angle Stop, Non-Return; Check, Stop-Check, Gate, Blow-Off, Mudline, Relief, Hydraulic, Instrument, Gage, and Special Valves and Strainers.

Hall Industrial Water Report

VOLUME 4 APRIL 1956 NUMBER 2

Corrosion—a Plague on All Our Houses

—presents problems as varied as industry, for all industry uses water in some way and all water causes corrosion to some extent. Thirty years of experience in thousands of individual plants enables Hall Laboratories to apply to current problems the most practical techniques for control of corrosion, many of them developed by Hall research and engineering.

Condensate System Saved

On his first visit to a new client, a hospital in Virginia, Hall engineer C. F. Raines encountered corrosion of the black iron condensate system so "terrible" that two men were kept constantly busy just replacing fittings and piping.

Both pitting and etching of the steel were occurring, suggesting that both dissolved oxygen and carbon dioxide were factors in the corrosion. However, the oxygen was not readily accounted for.

Raines examined the feedwater heater and found there was no way for the steam from the deaerating section to pass to the vent condenser. A tee had been installed in the line to take care of this, but instead had been used for a condensate line from the laundry. By proper rearrangement of connections, adequate venting was obtained as had originally been intended.

Additional changes included feeding 1 ppm. of Hagafilm® to the boilers to inhibit return line corrosion, and Santosite to react with residual oxygen not removed in the feedwater heater. Condensate line corrosion became negligible. Instead of replacing the entire condensate system at a cost of several thousand dollars, the plant now protects the system chemically at a cost of 17 cents a day.

Gasket "Corrosion" Problem Quickly Solved

Attack of boiler handhole gaskets at the pressure points of the locking clamps—center top and center bottom—on the sealing surfaces was experienced at a plant in West Virginia serviced by Hall engineer Wm. J. Reese.

At first it was thought that a highly-concentrated solution of caustic had dissolved the asbestos packing.

This possibility was rejected when it was concluded, after careful examination, that the gaskets had been distorted due to excessive pressure applied to the extremities of the minor axis in order to prevent leakage at the ends of the major axes. Subsequent investigation revealed the machined surfaces of the seats did not overlap properly at the ends of the minor axes, and the high points coincided with the areas of attack on the damaged gaskets. Refinishing the gasket seats eliminated the problem.

Bacterial Growths Get the Air

Severe corrosion under rusty deposits in an ammonia condenser prompted a food processing plant in Ohio to call on Hall Laboratories for help. Suspecting iron-fixing bacteria to be responsible for the hydrous ferric oxide deposits, Sales Engineer J. M. Harvey sent samples of water and a sample of wet deposit to Pittsburgh for investigation.

Bacteriological examination showed both iron-fixing and sulphur bacteria in the well water. Chemical examination showed the water to be high in bicarbonate hardness, with approximately 2 ppm. of iron and manganese in solution. Chlorination of the water was needed to kill the living organisms, but this would oxidize the iron and manganese and cause them to deposit, even though the iron-fixing bacteria which had been causing this were eliminated. Harvey met this dilemma by recommending stabilization of the calcium carbonate, iron, and manganese by continuous feed of threshold amounts of Calgon directly to the bottom of the well, followed by intermittent addition of hypochlorite to the discharge side of the well pump.

But this plant had everything. Now a different problem developed with an accumulation of slime in the condensers. In a new sample of wet deposit, Hall Laboratories found sulfate-reducing bacteria. Since these peculiar "bugs" thrive only in the absence of oxygen, continuous aeration of the well water was recommended to supplement the intermittent chlorination.

Operating experience has proved that aeration has been decidedly beneficial. There have been no condenser outages for cleaning, whereas formerly cleaning was necessary several times each summer.

These Whistles a Bargain, Sir!

In a Michigan plant the original soot blowing system lacked the whistles normally installed. When the steam valve was shut off after soot blowing, the vacuum produced drew gases from the ash pit through the drain into the piping. Severe corrosion resulted. Correction involved installation of the whistles to prevent vacuum by acting as vents.

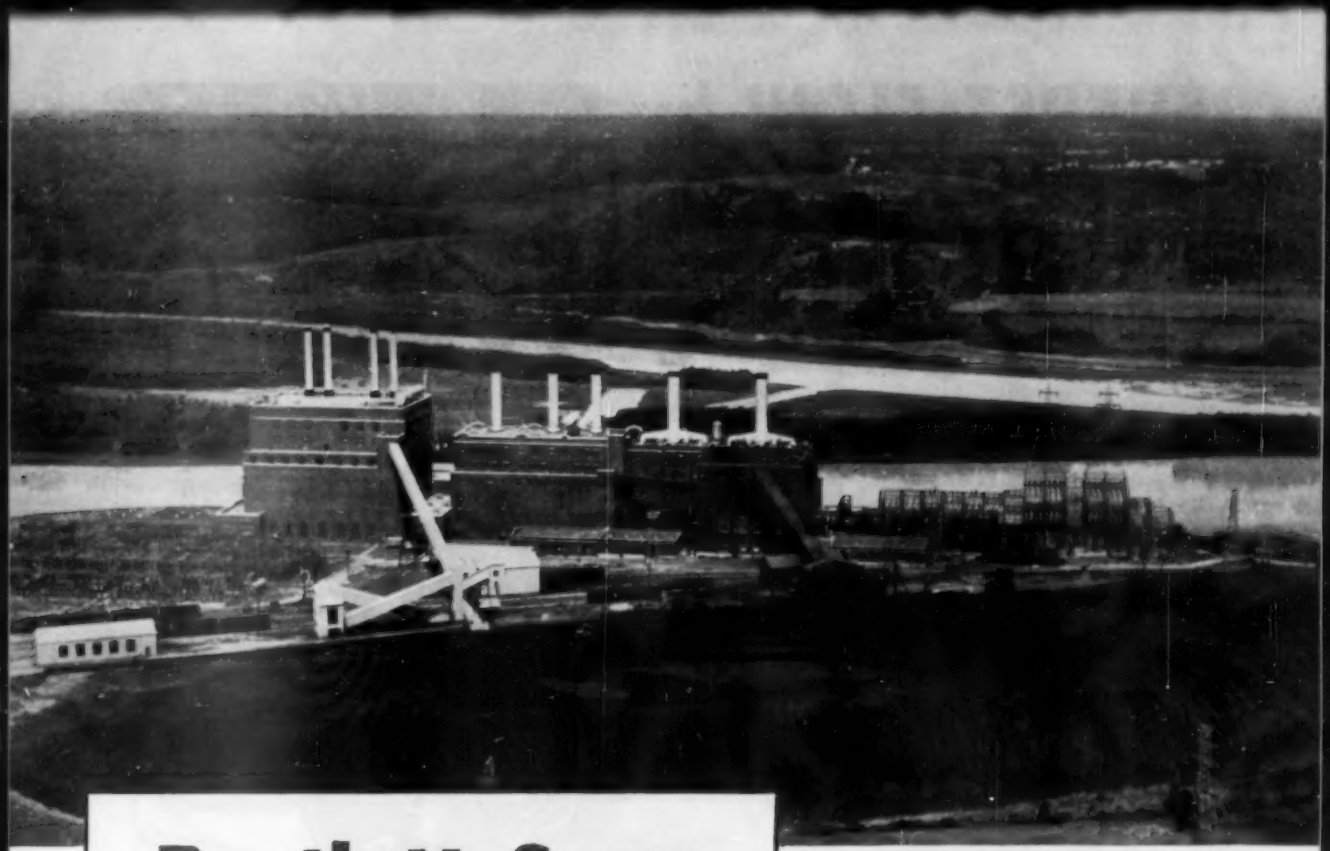
Ben Franklin's advice to consider alternatives before buying a whistle lest disappointment prove payment too dear for the choice could thus be answered, "*These* whistles were a bargain, Mr. Franklin."

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information write, wire or call Hall Laboratories, Inc., Hagan Building, Pittsburgh 30, Pa.

Water is your industry's most important raw material. Use it wisely.

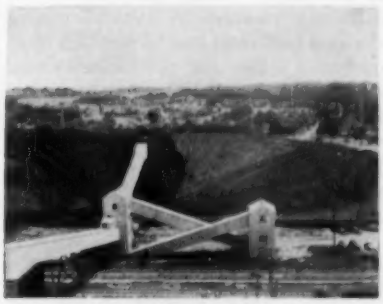
Hall Laboratories, Inc.—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water



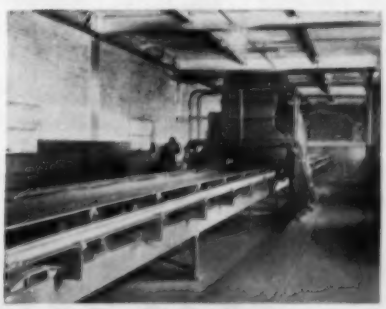
Above: Aerial View of Buck Steam Station
Duke Power Company
Spencer, North Carolina

Bartlett-Snow coal handling at Buck Station

● The large view above shows the Duke Power Company's Buck Station after completion of a 270,000 K.W. extension that increased the capacity of the plant to 460,000 K.W. maximum continuous capability. The new, completely self contained coal handling system required for the plant addition was designed by Bartlett-Snow working with Duke Power engineers. It has capacity of 500 tons per hour using 36″ belts and includes track and reclaim hopper, feeders, belt conveyors, crusher, sampler and automatic tripper. Let Bartlett-Snow central station coal handling engineers work with you on your next new plant, plant extension or modernization project.



General View of Coal Handling System
Showing Storage Conveyor



View of Distributing Belt Showing
Automatic Belt Tripper

DESIGNERS ENGINEERS

BARTLETT B-SNOW
CLEVELAND 5, OHIO

FABRICATORS ERECTORS

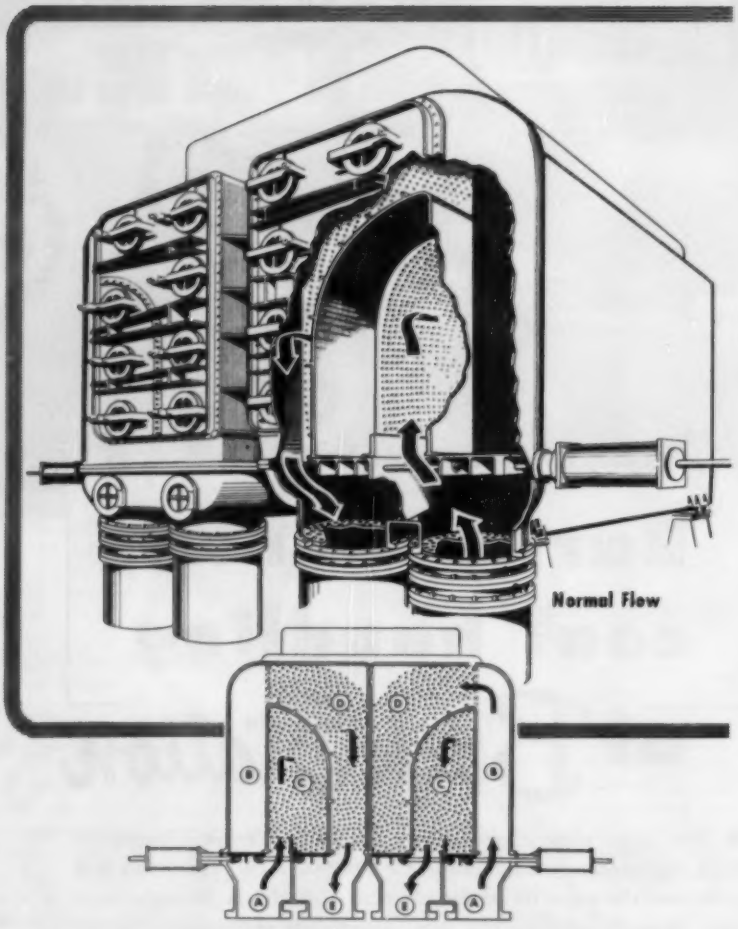
"Builders of Equipment for People You Know"

REVERSE FLOW by C. H. WHEELER
Cleans Steam Condenser Tube Sheets Without Loss of Load

When debris and organic growth collect on the tube sheets of a C. H. Wheeler Patented Reverse Flow Steam Condenser, you don't have to shut it down for cleaning. It cleans itself—without loss of load. Sluice gates arranged within the condenser may be controlled, either electrically or hydraulically, to reverse the flow of cooling water through the tubes. This sudden reverse flow literally flushes away leaves and debris, dislodges crustaceous matter from clogged tubes.

Because of 100% water flow during back flushing, there is only a negligible dip in vacuum momentarily, thus permitting continuous load on the turbine The Reverse Flow Condenser cleans itself in minutes, compared with hours of downtime when tube sheets are manually cleaned. A typical report shows a half-inch loss of vacuum (due to fouled tubes and tube sheets) was restored in five minutes after reversing the flow of cooling water. Often, a C. H. Wheeler Reverse Flow Condenser goes two years or more without shut down for cleaning, depending on the condition of the cooling water.

New, exclusive deaerating features and construction techniques help make C. H. Wheeler Steam Condensers "First in Efficiency." Let C. H. Wheeler Custom Engineer your next steam condenser. Phone or write C. H. Wheeler Manufacturing Co., 19th & Lehigh, Philadelphia 32, Pa. . . . Manufacturers of Steam Power Plant Condensers • Vacuum Equipment • Marine Auxiliary Machinery • Water Supply, Drainage and Circulating Pumps



HOW "REVERSE FLOW" WORKS

Left Side Shows Normal Operation

Water enters inlet A with right port open. Flows through tube bank C to rear of condenser . . . returns through tube bank D to front of condenser and discharges at E.

Right Side Shows Reverse Flow

Sluice gates move on a common stem. Water flows up through channel B, and through tube bank D to rear of condenser . . . returns through tube bank C to front of condenser.

In the C. H. Wheeler Divided Water Box Design, each half of the condenser can be back-flushed independently.

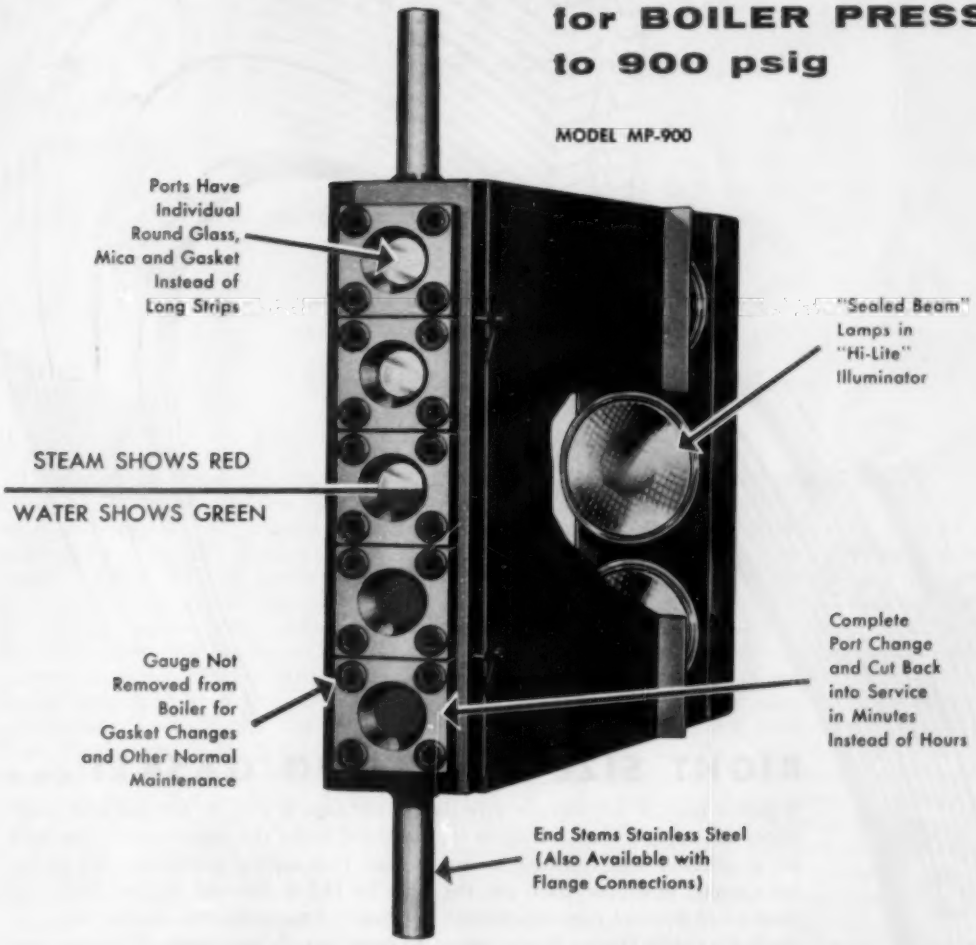
WE603

C.H. Wheeler OF PHILADELPHIA

Announcing ...DIAMOND "Multi-Port" Bi-Color Gauge

for BOILER PRESSURES to 900 psig

MODEL MP-900


Ports Have Individual Round Glass, Mica and Gasket Instead of Long Strips
"Sealed Beam" Lamps in "Hi-Lite" Illuminator
STEAM SHOWS RED
WATER SHOWS GREEN
Gauge Not Removed from Boiler for Gasket Changes and Other Normal Maintenance
Complete Port Change and Cut Back into Service in Minutes Instead of Hours
End Stems Stainless Steel (Also Available with Flange Connections)

The individual round ports each having its own round glass, round mica and round gasket (instead of the conventional long strips) means less stress and strain . . . resulting in greatly reduced maintenance. When replacement is required, it is usually only one port . . . which can be changed in a very few minutes . . . and without removing the gauge from the boiler.

The Diamond Bi-Color feature is another important advantage of the MP-900 Multi-Port . . . steam always shows red and water always shows green. There can be no question of the water level.

Recommended for both new and old boilers up to 900 psig, the MP-900 Multi-Port will give you a new standard of gauge operation. Use the coupon below for additional information.

7358

DIAMOND POWER SPECIALTY CORP.
LANCASTER, OHIO

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DIAMOND POWER SPECIALTY CORP. V
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Please send me without obligation a copy of new Bulletin No. 2044 explaining the advantages of the Diamond MP-900 "MULTI-PORT" Bi-Color Gauge for all boiler operating pressures up to 900 psig.

NAME_____

COMPANY_____

ADDRESS_____

RIGHT SIZE . . . WRONG GASKET . . .

A gasket may fit but still not give the proper seal. It may be too *soft* and crush under the applied load. It may be too *hard* and resist the compression necessary for an effective seal, resulting in bolt fatigue. Two sealing problems—one calling for a gasket to support 3285 psi, the other for 13,500 psi—call for two Flexitallic Gaskets of different densities though the gasket dimensions may be the same . . . Each Flexitallic Gasket is engineered to meet specific conditions of thermal and physical shock, corrosion, vibration, weaving and unpredictable joint stresses. Spirally wound V-crimped plies of required metal with alternating plies of proper filler results in a resilient gasket having characteristics of a calibrated spring. Flexitallic Gaskets are at highest efficiency when bolted up cold at a pre-determined load. For all pressure/temperature ranges from vacuum to 4000 lbs., from extreme sub-zero to 2000° F. For all standard joint assemblies. In four thicknesses for special requirements: .125", .175", .250", .285". With Teflon filler for corrosive chemical conditions. Write us your requirements . . . Flexitallic Gasket Company, Eighth and Bailey Streets, Camden 2, New Jersey. Representatives in principal cities. Consult your Classified Telephone Directory.

Flexitallic®
SPIRAL-WOUND GASKETS

FOR PIPE FLANGES, PRESSURE VESSELS AND PROCESS EQUIPMENT

*Flexitallic is a registered trade name. No one else can make a Flexitallic Gasket. Look for *Flexitallic Blue*—it's our exclusive blue-dyed Canadian asbestos filler.

Editorial

The Plight of the Program Chairman

The recently concluded American Power Conference, reported in some detail in this issue on page 63, was, in our opinion, one more in a series of successful meetings achieved by those who sponsor and organize this conference. Yet, if one were to rely solely on the reactions of the audience at the various sessions as a measure of the meeting's success there could be a different and, we believe, an erroneous conclusion drawn.

Every program chairman strives for good papers by capable speakers on subjects of high interest to the audience he hopes to attract. In the main the American Power Conference achieved this goal. Attendance at the individual sessions were all that any program chairman could desire, but the looked for indications of audience enthusiasm—discussions and questions—were not forthcoming. How, then, does a program chairman gage the effectiveness of a program of the American Power Conference's stature?

In our opinion the technique the Power Conference employs is unbeatable for a particularly effective program. They invite papers selected by a qualified committee which has been drawn together to plan for this single meeting the subjects of interest to one industry, namely that freely described by the blanket title of the power field. This concentration of talent brought to bear on a single target produces top results.

The absence of audience participation at the majority of the sessions this year in Chicago was, we felt, a tribute to the high level of the program. The subjects discussed were frequently ones which the audience members knew were "just around the next corner" as far as their own power plant experience was concerned and they welcomed the opportunity of peering into the immediate future even though they were not yet prepared to question or interpret against their own personal experience the information they were hearing. Obviously this type program places a tremendous burden on the program chairman since his program can only be as good as his advice. Up to the moment the chairman's advice and his handling of it has been excellent. We hope he can continue to draw help from the same sources and maintain the American Power Conference program at its present enviable standing.

In brief, the American Power Conference has succeeded admirably in mirroring the progress of a fast-moving industry and in reporting on the investigations underway to further that progress. We salute those who plan this Conference and wish them continued success.

High-Capacity Two-Furnace Boilers*

E. M. POWELL

Executive Assistant to Vice President
Combustion Engineering, Inc.

Today's twin furnace boiler designs, in the author's opinion, are a natural development to meet the increase in unit sizes, throttle pressures and temperatures in the power generation field. Their success for the projected average unit of 1960 seems assured by the application of controlled circulation techniques and tangential burner firing methods.

WITH all of the publicity being given to the dramatic developments in the field of nuclear energy one might ask what there is about high-capacity two-furnace boilers to capture the engineer's imagination.

Advances in the art of steam generator design have been remarkable over the past ten years and promise to be even more so in the years immediately ahead. To fully appreciate the significance of this subject, which is large separated furnace boilers, it would be interesting to review some of the pertinent statistics and see what our next objectives are to be.

Report On Growth

We have all heard or read reports of the growth of the electric utility industry, that it has doubled in capacity every ten years for the past thirty or more years. This growth cannot help but have its effect on the size of boiler turbine units which can be installed economically in any given system.

Fig. 1 shows capacity or rated kw for each year from 1945 to 1955 inclusive. The scale has been extended to 1960 to indicate the size units which will be purchased in that year.

The lower curve represents the average reheat unit size purchased in any given year as reported to the Association of Edison Electric Illuminating Companies.

The use of reheat was reborn in 1946 and now represents nearly all units being installed by the larger utility systems. The rate of growth has been such that the size has nearly doubled every ten years, which corresponds very closely to that of total power production. By 1960 then the average size reheat unit will be between 200 and 250 mw which should be very easy to realize in view of the number of units this size or larger which are already in operation.

The largest units sold by Combustion Engineering, Inc. in any one year are given in the upper curve. We have already reached units of 325 mw and are even now preparing proposals for 450 mw. There is no question but that units as large as 500 mw will be purchased by 1960 as the curve indicates. In fact, it would be surprising if this were not accomplished before that time. Taking all these statistics into account it should be safe to predict that the average installation purchased four years from now will be between 200 and 250 mw as indicated.

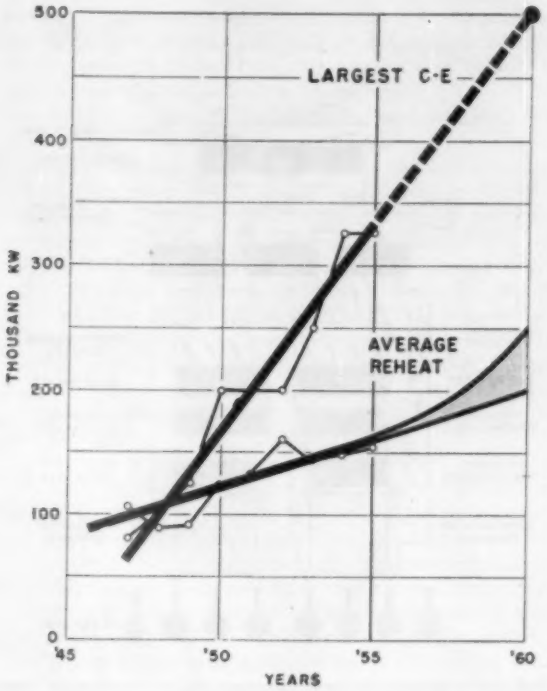
Before developing the effect of unit size on steam generator design it would be well to develop the probable steam conditions of pressure and temperature. Fig. 2 shows average steam pressure at the turbine throttle for all reheat units purchased in a given year. There has been a remarkably steady increase throughout the period shown at a rate of 73 psi per year. Indications are that an average throttle pressure of 2300 to 2400 psi will be reached by 1960.

Designing for Higher Pressures, Temperatures

At the present time there are a number of units in operation, others under construction, and more on the drawing board to operate between 2350 to 2500 psi at the throttle, using conventional designs. Naturally, to reach an average of 2300 psi for all reheat units, many must be designed for higher pressures. Considering power plant economics and good operation it would appear that the next logical step toward higher standard throttle pressure will be to something like 3500 psi, which is, of course, above the critical pressure of steam. This will require a departure from conventional boiler designs using the recirculation principle and necessitate the use of the once-through principle. While such designs have not been used commercially in this country to date they have attained considerable acceptance in Europe as built by Sulzer Brothers, Ltd. in Switzerland, or Benson licensees in Germany. By the end of 1958 we will have four such units in operation representing approximately 900,000 kw capacity and ranging in pressure from 2400 to 5000 psi at the turbine throttle. With this background of experience there is no doubt of our ability to achieve the objective of 2300 to 2400 psi average by 1960.

Steam temperature is the third important factor which exercises a real influence on the design of a steam generator. The average throttle temperature for all units over 12,500 kw purchased in a given year is plotted on the lower half of this illustration. It will be noted that the average yearly increase is at a rate of nine degrees per year and will reach an average of 1060 F in 1960. The last three years have not shown the same rate of increase as had been experienced earlier. This has been characteristic of steam temperature trends over the past 50 years. Advances in temperature have always proceeded in steps. Before a new cycle will be adopted generally by the industry there must be the background of success-

* Presented before the American Power Conference, sponsored by the Illinois Institute of Technology, March 21-23, 1956.



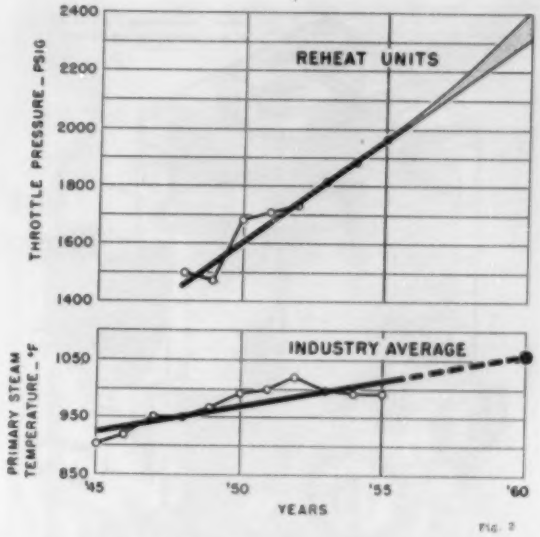


Fig. 1—Curves (left) show for upper set the growth in point of rated kw capacity per unit for each year for largest units purchased by the utility industry; heavy black line shows trend. Bottom set gives average reheat size

Fig. 2—(Above) curves show industry averages for steam pressures for reheat units, top curve, and for primary steam temperatures, bottom curves, with trend lines included

ful experience as built up by some of the larger systems which have pioneered this next step.

At present 1050 F has been accepted as a proved temperature. Several units are already in operation at 1100 F, two of which have operated successfully for more than two years. Others are being designed and constructed, one of which will be for 1200 F. With this much development and background of experience our indicated average of 1060 F by 1960 should be within reach.

The average unit four years from now will then be designed for a capacity of 200 to 250 mw to supply steam to the turbine throttle at 1060 F and 2300–2400 lb pressure. It will have one stage of reheat at the same temperature or slightly lower. It must retain or improve upon the basic characteristics of past designs. It is not sufficient to merely extrapolate from past standards. It must be functional making the most economical use of space and supporting steel, and at the same time accommodate more burners and larger pulverizers. Proper relationship between furnace volume and wall surface must be provided for efficient combustion and heat transfer.

It must have a high degree of flexibility to obtain maximum efficiency over a wide range of loads with means for regulating steam temperatures and hold them constant over that range. There can be no sacrifice in simplicity of operation.

Boiler availability records have been improving constantly. For instance, the average Combustion Engineering reheat unit operated last year with an outage time of less than four per cent which could be attributed to the steam generating unit. To continue this record with higher steam pressures, which result in higher saturated steam temperature and increased tube thickness, indicates the adoption of the controlled circulation principle as discussed before the American Power Conference in 1954 in the author's paper "Performance of New Controlled Circulation Boilers." In that paper we discussed such items as positive circulation, lower metal temperatures in the furnace through the use of small diameter tubes, improved means for separating water from steam, and reduced outage time by increased rate of starting and cooling accompanying a shutdown.

Separated Furnace Units

These are some of the more important considerations that led to the design of separated furnace units which is the subject of this discussion. Eleven of these units have been placed in service to date. They range in pressure from 1800 to 2500 psi at the throttle with steam temperatures of 1000 to 1053 F and capacities of 200 mw. The first of these was designed for Cromby Station Unit No. 2, of Philadelphia Electric, which started commercial operation August 1955. The first unit at Kingston started November 1954 followed by four others in the same station, three at John Sevier, then State Line, and now the No. 4 unit at East Lake. All of them are of the controlled circulation design. All are direct fired with pulverized coal covering a wide range of characteristics as found in the eastern and midwestern bituminous seams. The State Line unit is representative of this design and will be used as a basis for a more detailed description of the basic design principles.

This unit, Fig. 3, consists of two identical furnaces, each fired with tangential burners located in the four corners, and of the dry bottom type. The finishing superheater is located at the outlet of one of the furnaces. Steam temperature is controlled by the burner tilt augmented by desuperheaters for emergency use.

The reheater surface is located at the outlet of the second furnace in the same relative position as the finish-

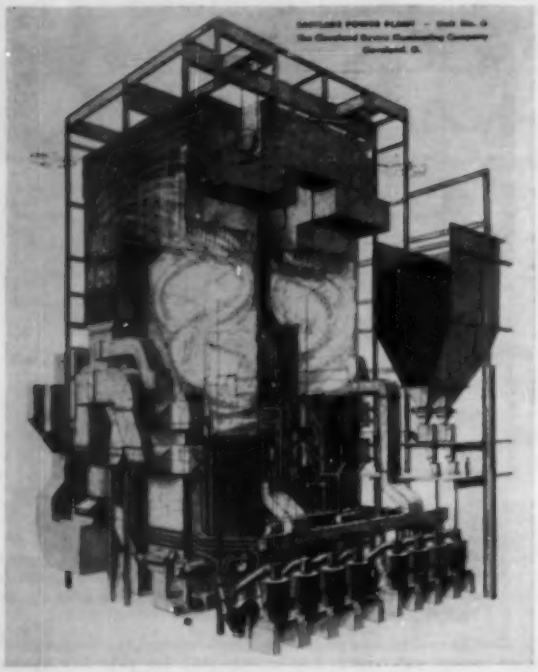


Fig. 3—Typical separated furnace unit employs two identical furnaces, fired with tangential burners with finishing superheater in one furnace, reheater in other

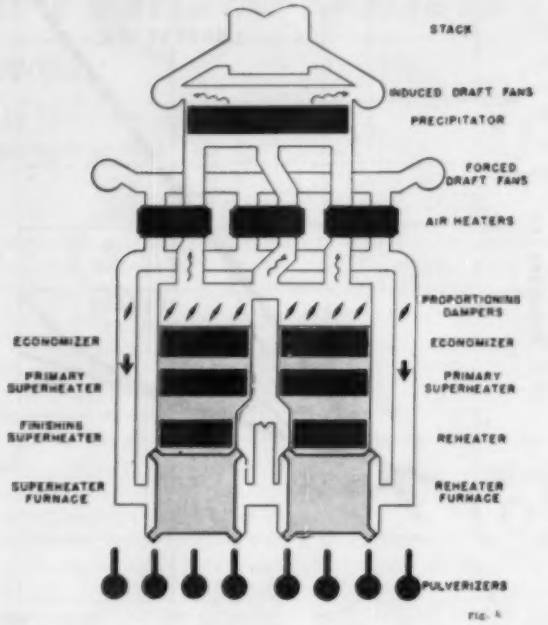


Fig. 4—Simplified control diagram shows the design divisions with the unit divided back to the economizer outlet. Note reheat, superheat arrangements

ing superheater. This makes it possible to control the gas temperature leaving the reheater furnace to satisfy the needs of the reheater as affected by load entirely independent of the superheater. A desuperheater has been provided in the inlet piping for emergency use.

Assuming Good Combustion Performance

Particular attention has been given to the burning of the poorer quality coals. The furnaces are sized to provide a low combustion rate and are completely water cooled with bare surfaces. With two separate furnaces we have gained the surface of the two additional side walls and all the walls are accessible for cleaning with wall-type blowers. The convection surfaces at the furnace outlets have been arranged in panels of tangent tubes or platens spaced 14 in. apart across the furnace width so they may be cleaned easily with retractible soot blowers. The surface behind these platens is also arranged on wide centers (7 in.) for ease of cleaning and to avoid bridging of ash. No difficulty in this respect has been experienced with any of the coals fired to date with the units of this type.

A wide variety of coals have been burned at State Line including that from the Pana mines. This is a coal which is high in chlorides and volatile alkalis and having low fusion temperature ash. These are characteristics which are indicative of potential difficulty with bonded deposits.

Tightness of the furnaces to avoid costly air leakage and ease of cleaning are two most important items to be considered as units increase in size and efficiency. To meet this problem at State Line the furnaces are constructed of solid welded waterwall panels which are completely pressure tight. One and one-half inch tubes are located on two-inch centers with a one-half inch bar between. The whole assembly is then completely welded in the shop to form a panel 4 feet wide by 40 feet long. These panels then are welded together in the field to form a solid metal wall. No additional casings are required with this design to insure absolute tightness of the setting. In fact it is being used successfully at Kearny Station with pressure firing. The potential value of this principle from the standpoint of erection costs for the larger units discussed earlier is quite apparent. Similar techniques have been applied to shop assembling tangent tube panels which are not welded but backed by a skin casing to form a gas tight barrier. Solid welded panels could be considered only when uniform temperatures can be assured through the use of controlled circulation.

Unit Controls

A simplified control diagram is shown in Fig. 4. Each of the two furnaces is supplied by four pulverizers, any three of which can meet the normal full load requirements. The unit is divided back to the economizer outlet. The economizers are the same in each half as are the primary superheaters. The finishing superheater is located behind the left-hand furnace and the reheater behind the right-hand furnace. Since the heating surfaces are arranged for equal heat pickup in each half, the control problem has been simplified to one of providing equal fuel and air supply to the two furnaces. The two burner tilts will automatically be adjusted to suit the varying needs of the superheater and reheater as affected by load variation. Of course, to accomplish this, provision must be made to bias the input which will make it possible to extend the range of constant steam temperature without resorting to the use of the desuperheaters.

Crossover gas and air ducts are provided at the back of the unit to permit operation with an air heater or fan out of service. There are three air heaters and two I.D. fans which discharge into a single stack. Two F.D. fans supply air through the air heater and divide to the two furnaces.

Average furnace draft is maintained through the control of the induced draft fans. The drafts in the two furnaces are made equal through the use of the proportioning dampers at the economizer outlet. One of the dampers will be kept wide open for minimum draft loss. The total air flow is matched with the fuel input and controlled by the forced draft fans. It is then distributed equally to the two furnaces or to match coal supply by the proportioning dampers in the air ducts. Oxygen recorders and controllers have been installed which may be incorporated in the control system for final regulation.

Operation of these 11 units has been quite satisfactory with little or no difficulty encountered in the control of air and distribution of fuel. Control of steam pressure and the water level in the single drum has been excellent.

Operating results in the field has demonstrated that flexibility has not been sacrificed with these larger units. Rather it has been possible to take advantage of size and increased flexibility with separate furnace design. This is particularly true during start-up where it is possible to raise steam pressure and load the machine quickly while offering maximum protection to the reheater metal. Fig. 5 will show the procedure followed on unit No. 5 at Kingston and some of the critical items to be observed during starting.

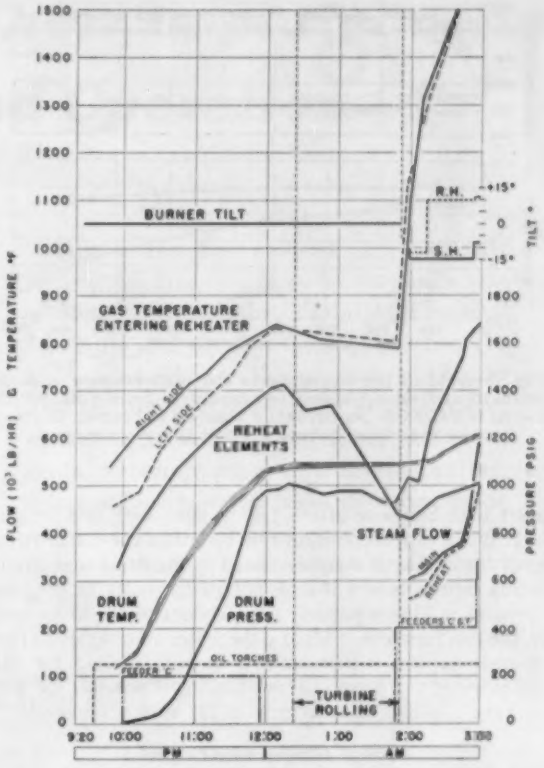


Fig. 5—Start-up procedure on the No. 5 unit at Kingston Station of TVA portrayed above gives good indication of time required and element reactions

Start-Up Experience

Oil torches were in service in both furnaces throughout the entire operation. One level of coal burners supplied by one pulverizer was fired in the superheater furnace until the unit was ready to start rolling and synchronizing the turbine. In this case that was done at 1000 pounds pressure.

It is essential to a proper start-up to maintain uniform temperature distribution throughout the pressure parts to insure uniform expansion of all parts and avoid unnecessary stresses. This can be controlled best by observing the temperature distribution throughout the steam drum. Twenty thermocouples were installed for this test covering all areas of the drum including steam outlet, downtake nozzles and the heads. The temperatures recorded by all of these couples can be plotted within the band indicated on this chart showing a maximum divergence from the highest to lowest of fifty degrees. The saturated steam temperature corresponding to observed drum pressure is not shown but lies slightly above the drum metal temperature. The degree of uniformity which has been achieved is a result of the rapid circulation and thorough mixing of water by the circulating pumps. It is of interest that the superheater furnace was fired at a rate more than three times that in the reheater furnace without disturbing uniform temperature distribution throughout the entire pressure parts system.

The maximum rate of heating occurred during the first hour and was at the rate of 250 F per hour. At no time prior to admitting steam to the reheater was the gas temperature leaving that furnace permitted to exceed 830 F which was quite conservative from the standpoint of protecting the uncooled reheater metals. The maximum temperature reached by a reheater element during this period was approximately 700 F.

The turbine was rolled and synchronized during the next period. Raising to normal operating pressure was done as the load was applied to the machine at the rate of 2 mw per minute, which was established by the turbine operators. Coal was fired to both furnaces equally during this period since the reheater was fully protected by steam flowing through it.

During the warm-up period the burners were held at a horizontal position. When steam was admitted to the turbine as load was added to the machine, the burners were depressed below horizontal so that the rate of temperature increase could be completely under the control of the operator. The burners in the reheat furnace were raised to above horizontal quite rapidly to increase the temperature of the reheat steam. The burners in the superheater furnace were brought up more slowly to regulate the rate of temperature increase to the throttle.

It will be noted that excluding the period when the turbine was being readied for loading the whole operation up to one-half load was accomplished in approximately three hours.

Results such as these demonstrate that the time required for starting a boiler turbine unit need not be limited by concern with temperature distribution and adequate circulation of water and steam throughout the boiler. This may be demonstrated more clearly in the future when the occasion may be presented for a quicker

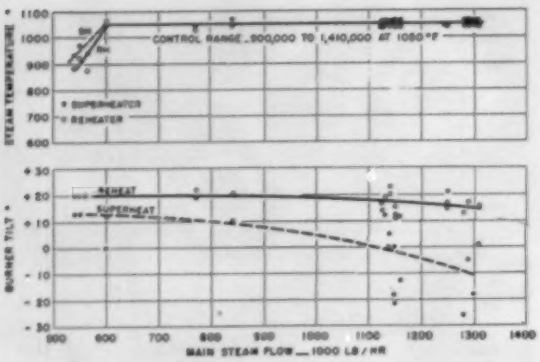


Fig. 6—Note in the upper curve the maintenance of both primary and reheat steam temperatures from 1,300,000 lb per hr to 600,000 lb per hr, better than a 2 to 1 ratio. Bottom curves show how burner tilt met this requirement

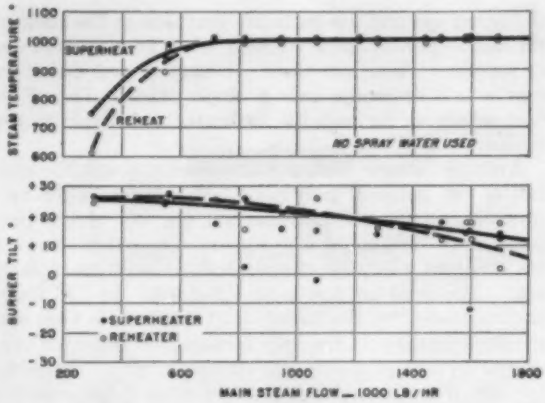


Fig. 7—Cromby Station, Unit No. 2, shows a performance similar to Kingston in Fig. 6

start than has been attempted to date with this design.

It is also apparent from this test that the water from each furnace is thoroughly mixed in the drum and circulating pumps before it is distributed equally to the two furnaces. This is entirely independent of the firing rate in the two furnaces. Mixing the water thoroughly in this manner insures representative water sampling for the guidance of the plant chemist making it possible for him to have absolute knowledge of boiler water conditions.

Final Temperature Control

Year by year as newer and larger units are to be placed in service it will become necessary to operate the present large units over a wider and wider load range. To do so efficiently makes it desirable that they be able to maintain constant throttle and reheat steam temperature.

To determine the steam temperature characteristics we have reviewed the charts and operator's log sheets and selected periods which will be representative of normal operation at a given load over as wide a range as possible.

Prior to the separated furnace design it was normal to guarantee constant steam temperatures to a minimum load of 65 to 70 per cent without resorting to the complication of gas recirculation or the use of desuperheating as a primary factor in the control system. All of these units have done materially better than that. For instance, on unit No. 5 at Kingston (Fig. 6) both the primary and reheat steam temperatures were maintained at 1050 F from 1,300,000 lb flow to 600,000 lb per hour or better than 2 to 1 ratio. The guaranteed range was from 900,000 to 1,410,000 as shown. The corresponding burner positions in the two furnaces are indicated below. They are generally higher at reduced load as would be expected. The wide scattering of points at the higher loads is indicative of the way in which the burner tilt will automatically compensate for variation in furnace cleanliness and the variation which results from firing at different levels in the furnace as the selection of mills and burners to be operated may be changed from day to day.

Unit No. 2 at Cromby Station is performing in a similar manner as shown in Fig. 7. Design temperature 1000 F of the primary and reheat steam has been maintained from 1,700,000 lb per hour to 700,000 lb per hour which is a ratio of $2^1/_2$ to 1. No desuperheating was done at any load and normal excess air was used throughout the range. The characteristic of burner tilt is quite similar to Kingston. This unit was designed for a maximum continuous load of 200 mw corresponding to a steam flow of 1,450,000 lb per hour and is operated consistently at 1,600,000 lb per hour.

State Line has been in operation for a somewhat shorter period than the others and has been carrying full load consistently around the clock. This has made it difficult to accumulate much representative data at reduced loads. That information which is available has been plotted in Fig. 8. The temperature characteristics promise to be at least equal to the other 1050 F units at Kingston. Here again no spray has been used. Burner tilts are shown in the lower curve of Fig. 8.

Conclusions

In conclusion, we have attempted to establish that the average utility system will purchase units larger than 200 mw in 1960 with some as large as 500 mw. They will be designed for at least 2300 psi throttle pressure and 1060 F with many above critical and 1100 F. We have also attempted to establish that the groundwork for such progress has already been laid and we may proceed with assurance of success. The separated furnace units have proved to be ideally suited to meet these conditions by their simplicity, flexibility and performance.

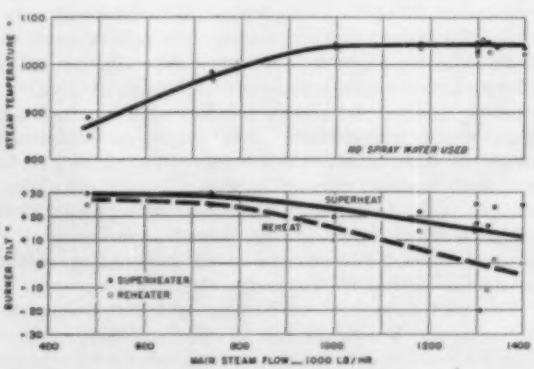


Fig. 8—Steam temperature and accompanying burner tilt curves for State Line twin furnace unit are pictured above

Coal Minerals and Their Importance to Boiler Design and Operation—I[1]

By WILHELM GUMZ

Dr.-Ing., F. Inst. F.[2]

This is the first section of a two-part article by Dr. Gumz, who formerly was a consultant to the Battelle Memorial Institute and who is widely known both in this country and in Europe as an authority on fuels and combustion. The author discusses origin and distribution of coal minerals, determination of mineral matter, effect of high temperatures upon coal minerals, and the influence of several types of firing upon the problems of fouling and slagging.

COAL burning is greatly affected by the mineral constituents of the fuel. Whereas experts are often inclined to say that the problems of reacting the organic matter of coal with the oxygen of the combustion air are solved and offer only limited possibilities or necessities for improvement, one cannot overlook the fact that the problems imposed by the mineral matter are of growing concern. As the rapid growth of energy and fuel demands continue, both the use of lower grades of fuel and the difficulties encountered thereby may gradually increase.

In contrast to the U. S., most of the European countries are compelled to use high-ash coals. Many power plants are burning high-moisture fuel, such as brown coal with 50 to 60 per cent moisture content, and the bituminous coal mines themselves use low-grade fuels such as middlings, slurry, dust, etc., which could not carry any transport charges because of their low heating values.

It is only natural that boiler operators using such types of fuel have acquired a certain amount of knowhow to handle the unavoidable difficulties connected with extremely high ash contents. It is understood, on the other hand, that the amount of ash or mineral matter is not as decisive as the type, and that difficulties do not increase in a linear function with ash content. In recent years, the situation has changed not so much because of a gradual decline of the fuel quality as because of the greater variety of fuels—including imported coals. Another factor has been the steady increase of unit sizes, of steam pressures and temperatures and, last but not least, of rates of heat release and furnace temperatures. A new era of combustion came into being when—during the reconstruction after World War II—slag-tap and cyclone furnaces rapidly came into general use. This development, which started years ago in a number of industrial countries, was not so much inspired by the hope of small gains in boiler efficiency and economy but by the necessity to get rid of the fly ash from precipitators and to get as much into the form of molten slag as possible. The disposal of fly ash is one of the most serious problems within the densely populated industrial areas of Continental Europe, and slagging furnaces offer at least an alleviation and a possibility to use or sell the residues of the coal combustion process for road making, building or brick-making purposes (3).

In this general trend of development it was suddenly felt that our knowledge of behavior of mineral coal constituents during combustion is by far insufficient, that former rules and recommendations (4–6) still hold but do not give the full answer, that there is no reason for complacency, and that the methods of assessing coal ash and slag characteristics and fouling tendency are inadequate (1). Special emphasis is required in the study of coal minerals, their reaction with carbon, the effect of high temperatures and high rates of heating. The problems of fouling and corrosion indicate clearly that even small amounts of certain constituents may become important because of the accumulative effect even of trace elements. The significance of metal oxides in oil ash may be taken as an illustrative example.

Origin and Distribution of Coal Minerals

The inorganic constituents of coal are of various origin (7–11). Only part of them has been accumulated by the plants forming the coal or laid down with the plant substance ("syngenetic ash") and, hence, would be characteristic for a given coal seam. Most of it has been carried into or has intruded the seam after its formation ("epigenetic ash") and must be regarded as an adventitious ingredient. Ash content as well as its composition, therefore, cannot readily be correlated with a certain type or rank of coal nor a certain mine or coal seam. On the contrary, it has often been observed that ash composition and fusion characteristics change within the same mine or even seam as working of the coal progresses.

The usual subdivision of ash into:

(1) syngenetic ash—including (*a*) plant ash and (*b*) adventitious minerals,
(2) epigenetic ash—including (*a*) primary and (*b*) secondary epigenetic minerals with or without continued supply of material

is of some importance to science and also from the point

[1] This paper is based mainly on two publications by the author in Mitt. V. G. B., 1954 and 1955 (1, 2). See bibliography at end of article.
[2] Steinkohlenbergbauverein, Friedrichstr. 2, Essen, Germany.

of view of coal cleaning (7–8). In addition no small part of the inorganic substance of high-ash coals may consist of shales from the bottom, the roof or from partings of shaley material within the coal seam which may have gotten into the coal during coal-getting operations. The separation of such uncombined material is rather easy by physical methods as employed in coal cleaning plants. Finely dispersed minerals, however, such as, for example, fine concretionary pyrites often encountered in coal defy the usual methods. For this reason desulfurization of coal is hopeless in the majority of cases.

The combustion engineer is less interested in the origin than in the actual mineral constituents of coal as fired. Table I lists the major types of minerals in bituminous coals. The first group is subdivided by Nelson (13) into the shale group and the kaolin group.

The clayey minerals, pyrites, and calc spars usually make up 95 per cent of the mineral content. According to the nature and origin of mineral components, ash composition of various products of the coal cleaning process also varies. Table II gives an illustration of this variety. The data given are the result of an extensive study of hundreds of coal samples from the Ruhr District (W. Germany) and the values are selected at the maximum of frequency. They may be considered as truly typical. Examples of frequency values are given in Figs. 1–3. This method of presentation of analytical data was first employed by Rosin and Fehling (15).

TABLE I—MAJOR MINERAL CONSTITUENTS IN BITUMINOUS COALS[12]

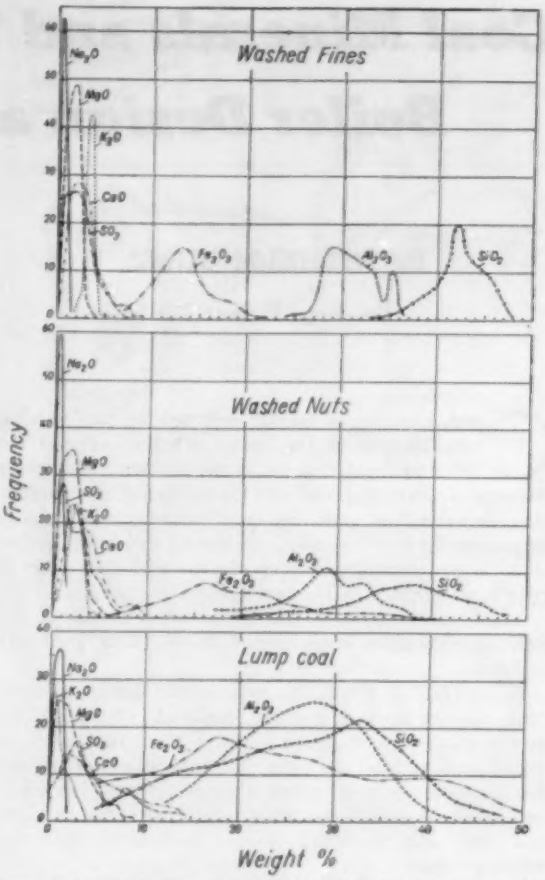
Mineral Components	Syngenetic	Epigenetic
Clayey minerals (Kaolin)	Fine clays to carbonaceous shale (Kaolin worms and grains)	—
Pyrites	Fine concretionary pyrite (FeS_2), impregnation of fusite	Pyrites in clefts and fissures
Spars	Small to large concretions ($FeCO_3$),	—
Siderite	impregnation of fusite	
Calc-spar and ankerite	Impregnation of fusite	In clefts and fissures
Quartz	Fine crystalline impregnations in coal, carbonaceous shale and Kaolin	In clefts and fissures
Zinc blende, copper pyrite, galena	Sporadically in small concretions with pyrite	In clefts and fissures

TABLE II—ASH ANALYSES OF BITUMINOUS COALS FROM THE RUHR DISTRICT (WEIGHT %)

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O
Lump coal	36.0	36.7	12.2	6.5	1.8	2.0	1.4	1.4
	32.5	29.7	15.3	8.5	3.5	6.8	0.6	0.8
	33.9	30.6	20.4	5.1	3.1	2.9	1.4	0.3
	35.9	29.5	16.0	6.1	2.6	2.0	1.0	2.8
Nut sizes	38.0	27.0	26.5	2.2	1.5	1.4	0.4	2.7
	38.5	29.2	20.4	2.0	2.2	1.7	0.7	3.1
	38.8	30.4	16.3	3.5	2.2	3.2	0.7	3.2
	38.3	29.3	17.6	4.2	2.3	2.6	0.8	2.6
Washed fines	42.2	29.5	18.9	0.9	1.9	0.6	0.6	3.0
	42.2	29.4	16.3	3.2	3.0	2.9	1.0	3.8
	44.2	32.1	12.8	1.8	1.8	1.8	0.8	5.5
	43.0	30.8	13.2	2.2	2.9	3.0	0.6	3.5
Refuse*	51.0	29.6	9.2	2.0	1.9	1.5	0.6	4.2

* After B. Daniels (+0.6 P_2O_5) (14).

Widely different from the ash of bituminous coals is the mineral matter of brown coal. Rhenish and Central German brown coal is rich in calcite whereas clay is very much lower (15). The chemical analysis shows CaO contents of 30–40 per cent, SiO_2 only 10–12 per cent, Al_2O_3 5–7 per cent, Fe_2O_3 2–4 per cent as most frequent values. SO_3 is very high but sulfate formation is very often taking place by reaction with SO_3 or SO_2 during heating. This type of ash is not characteristic for all types of lignites. Bohemian lignites, e.g., have an ash composition which resembles very much that of bituminous coals.



Figs. 1–3—Frequency curves of analytical data on ash analyses of Ruhr coals

A special type of coals containing large amounts of chlorides and also sulfates are the so-called salty coals, brown coal located below salt deposits and impregnated with these salts as in some parts of the Central German brown-coal deposits (10). They are extremely difficult to handle in the furnace and require specially designed furnaces and boilers (16). Salt contents are as high as 5 to 25 per cent, calculated as Na_2O in the coal ash.

Chlorine in bituminous coals and coke is less frequent. According to British (17) and German authors (18) chlorine originates mainly from chlorides which are either impregnated into the coal or added by the wash water (mine water) during cleaning process. The use of salt as an aid in the precipitation of dust in underground workings is another source of unwanted quantities of alkalies and chlorine in coals. The expressed view of Edgcombe (19) that chlorine does not mainly originate from chlorides but still to be water-soluble is not shared by other workers. The emphasis on the part played by the (rather small) alkali content of coal has led to improved analytical methods. Flame photometry which allows the separate determination of Na_2O and K_2O and other alkali and alkali earths has come into use more and more, also because of the speed and accuracy of determination.

Determination of Mineral Matter

The chemical analysis of coal ash—from a practical

point of view—is not as significant and not unambiguous. It is, therefore, not fully sufficient for the assessment of a coal ash and its eventual behavior in the furnace. The chemical components may belong to a variety of minerals as indicated in Table III. With a given chemical analysis a number of possibilities of mineral analysis could be found in accordance with the chemical analysis. As an illustration the following analysis of coal ash—SiO_2, 44.00%; Al_2O_3, 27.23%; MgO, 1.81%; Fe_2O_3, 12.71%; CaO, 5.50%; SO_3, 3.75%; CO_2, 5.00%—could be interpreted in four (or many more) ways as shown in Table IV.

TABLE III—CORRELATION OF CHEMICAL ANALYSIS AND INITIAL MINERAL COMPONENTS (AFTER MACKOWSKY)

SiO_2	Al_2O_3	Fe_2O_3	CaO,* MgO*	SO_3,* P_2O_5*	Alk.
Kaolin	Kaolin	—	—	—	—
Sericite	Sericite	—	—	—	Sericite
Biotite	Biotite	Biotite	—	—	Biotite
Feldspar	Feldspar	Feldspar	Feldspar	—	Feldspar
Quartz	—	—	—	—	—
Montmorillonite	Montmorillonite	—	—	—	—
		Siderite	—	—	—
		—	Calc-spar*	—	—
		Ankerite	Ankerite*, *	—	—
			Dolomite*, *	—	—
		Pyrite	—	Pyrite	—
		Haematite	—	—	—
		Apatite	Apatite*	Apatite	—
		—	—	Coal	Coal (?)

TABLE IV—POSSIBLE MINERAL COMPONENTS OF THE CHEMICAL ANALYSIS GIVEN (AFTER MACKOWSKY) (20)

	I	II	III	IV
Clay	95.5%	85.7%	91.4%	85.1%
Quartz	0.6%	3.1%	1.7%	3.5%
Pyrite	1.4%	1.5%	1.4%	—
Siderite	2.5%	—	—	2.1%
Haematite	—	7.5%	3.3%	5.4%
Calc-spar	—	2.2%	—	—
Magnesite	—	—	2.2%	2.4%
Organic S	—	—	—	1.5%
	100.0%	100.0%	100.0%	100.0%

It is quite obvious that any correlation with chemical analyses or characteristics derived therefrom must result in more or less wide scattering and that the aid of the mineralogist is required to fully understand the behavior of coal in the combustion process.

Earlier the main efforts were directed toward the determination of the total mineral content—as differentiated from the ash content, a merely conventional value of residues under controlled conditions of combustion (but differing from the conditions in an actual furnace). The Parr formula is very well known. The most elaborate formula is that of King, Maries and Crossley (KMC-formula)(21) which reads

$$M = 1.09\,A + 0.5\,S_p + 0.8\,CO_2 - 1.1\,SO_{2(ash)} + SO_{2(coal)} + 0.5\,Cl$$

(M mineral matter, A ash, S_p pyrite sulfur.) It is somewhat cumbersome and time consuming and not quite practical for uses other than scientific investigations. Brown, Caldwell and Fereday (22) have simplified this formula for British coals (with some exceptions) to

$$M = 1.06\,A + 0.53\,S + 0.74\,CO_2 - 0.32$$

excluding organic sulfur. Fereday and Flint (23) have suggested a slightly different version (including organic sulfur)

$$M = 1.058\,A + 0.67\,S + 0.66\,CO_2 + 0.30$$

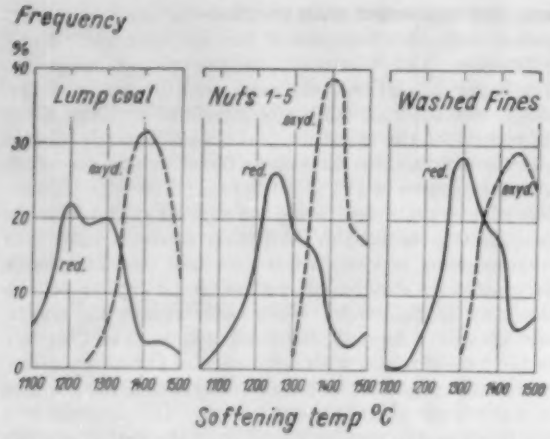
Any further improvement to such formulas, by increasing the number of samples to more than 1400 already used, is of no avail, because the inadequacy or limitation to certain areas stems from lacking knowledge of the true mineral components present.

Unfortunately, the mineral analysis (24–26) is less easy and convenient than the chemical analysis and requires expensive equipment for spectroscopic, X-ray diffraction, and electronic microscope examinations. The X-ray diffraction is the most versatile tool in mineralogy, but the coal substance interferes with the X-ray diffraction of the minerals, and minerals partly change and disintegrate by the conventional ashing procedure at temperatures of 775 C ± 25 (1427 F ± 45). Therefore other ways of separating the mineral matter from the coal have to be sought. All these methods have their corresponding process in full-scale coal cleaning plants. In most cases enrichment suffices as a complete separation may be impossible. Such methods are: the separation by weight as in the float-and-sink analysis (jigging), or the pulverization with separation of the air-entrained material in a cyclone or a series of cyclones, the grinding in water with oil added to wash away the minerals with the water and to remove the oil from the coal afterwards (after Quass (27)) as in the Trent and Convertol Process, and the removal of the organic matter by strongly oxidizing solvents such as hydrogen superoxide, perchlorates, etc. One of the most promising methods seems to be the mild oxidation at temperatures not exceeding 380 C (716 F) as used by Nagelschmidt and Hicks (28) and again suggested and improved by Nelson (13). Other methods used for special purposes only, such as determination of the total mineral content (without analysis of its composition), may be the solution of the minerals by acid solvents or the determination of all organic constituents, including oxygen, to get the mineral matter by difference.

Regarding the details of determination, it may suffice to point to the abundant literature existing on the X-ray diffraction methods. The ASTM card index of diffraction data for the interpretation of the diffraction patterns (Debye-Scherrer-Hull diagrams) has proved a most valuable tool. By replacing the X-rays by electron rays the electronic microscope may be used not only for the morphologic examination of the sample (29) but also for the study of diffraction patterns of coal minerals (30).

Behavior of Coal Minerals at High Temperatures

It is well known that the coal minerals undergo a number of changes when heated (31). First the moisture bound in the lattice structure is removed; CO_2 is expelled by the disintegration of the carbonates; pyrites decompose by the loss of one, later the second sulfur atom; the clay minerals decay, mullite is formed, also iron and calcium silicate melts, and cristobalite. These latter processes are commonly regarded as slag formation or slagging. Because of its complexity it has usually been studied only by technological tests such as the ash fusion characteristics and the viscosity of the resulting slag. The well-known Bunte-Baum method (32) has been improved by the use of the Leitz heating microscope, a method which has been standarized in the DIN-industrial standards (33). The results, however, are not entirely satisfying. The obvious reason again lies in the deviation from full-scale conditions. The sample is finely ground, well mixed coal ash, which is already modified by the procedure of (standardized) ashing; most of the minerals are changed into oxides. Unfortunately, however, calcite defies a complete removal of its CO_2 at these rather low temperatures, although a partial de-



Figs. 4–6—Frequency curves of softening temperatures (semi-spherical point) of Ruhr-coal ashes

acidification has taken place. The correlation of actual furnace behavior differs more and more from such tests, the higher the temperatures are, as well as with increased rate of heating (20). In a pulverized-coal furnace, for example, there is neither such mixing of components nor a two-stage heating process of ashing and slagging but the minerals go to the final phase of slag within a fraction of a second.[1]

Disregarding the inadequacy of the methods of determining fusion characteristics, it is recognized that this method has its merits in some cases and will continue to be accepted as long as nothing better is on hand. The variations shown in the different products of a coal cleaning plant with regard to ash analysis also appear with softening temperatures ("semispherical point"). Figs. 4–6, show some frequency data of softening temperatures of Ruhr coals in reducing and oxidizing atmosphere (the influence of the atmosphere being 150 deg C (270 deg F) difference in all cases).

The characteristic temperatures of the initial deformation, of softening and the fluid temperature are only one indication; other conclusions may be drawn from the range of the melting zones whether or not fusion and fluid temperature are close together ("short slags") or far apart ("long slags"). Another important characteristic is the rate of recrystallization. Short slags which are high in iron and calcium oxide and low in silica are of low viscosity and have a tendency to crystallization and to quick solidification whereas long slags will slowly solidify into a glass-like material (34). The time factor is an important one for many practical cases, and it could well be that the measurement of electrical resistance as used by W. Werner for salt compounds as well as for slag could be helpful (14). Similar investigations on the constitution of slag have been conducted at the Max Planck Institute for Steel Research (Düsseldorf) by Fischer and vom Ende (35).

In an earlier attempt to a better understanding and interpretation of Bunte-Baum data, Zinzen presented the results in a triangular diagram, using $SiO_2 + Al_2O_3$, $Fe_2O_3 + FeO$, and the remaining components as the third coordinate (36). It has found some acceptance in the literature (31). The advantage was not so much a satisfying correlation of data, but the possibility of classifying coal ashes and slags into certain types of such diagrams and was clearly understood and expressed by Zinzen himself. The root of possible failure comes from the fact that the correlation starts from chemical rather than mineralogical data. The evaluation of the chemical analysis, e.g., by the Niggli values (38) or similar methods used in mineralogy may lead to improved methods.

Finally the measurement of slag viscosity is of great interest to the combustion engineers in connection with the increased spreading of slag-tap furnaces. The late Prof. Endell has made valuable contributions in this field; his characteristics are of some help in the assessment of slag behavior and in the selection of addition for changing viscosity characteristics (34). One factor, however, that may require more attention in future research is the effect of temperature, duration and rate of heating on the partial volatilization of the slag (and slag sample) on its composition and, hence, its viscosity.

The Influence of Furnace Design and Operation

Apart from slagging in fuel beds the second main group of practical troubles connected with the mineral matter of coal relates to the various types of fouling of the boiler heating surfaces. These include slag deposits at the furnace walls, formation of bonded deposits in the convectional heating surfaces, in superheaters, economizers and air heaters. Although significant progress has been made on all these problems, centered around boiler availability, it is generally agreed that problems are utterly complex, that no explanation so far offered by various workers—sometimes of a somewhat contradictory nature—leads to a full understanding of all possible cases, and that much work is left to be done.

There are a number of "critical" factors. To mention only a few concerning temperature, they may be listed as follows: The maximum actual temperature occurring in a furnace or in a fuel bed depending upon the type and composition of fuel, the specific rate of firing, and the air preheating temperature, the duration of the combustion process depending upon the size of fuel (from lump to finely ground), the temperature of the gases leaving the furnace and along the gas path throughout the boiler, the temperature of entrained solid particles which depends upon the state of burn-out (whether they are completely turned into slag or still in a slow-rate of burning), the temperature of the surfaces as well as the nature of these surfaces including the nature of smaller or larger deposits at these surfaces and the possibility of catalytic reactions being induced by them.

With reference to this list it is quite evident that various types of boiler furnaces will result in a different behavior of coal minerals even when burning exactly the same fuel. Therefore, it is a prerequisite to discuss various types of furnace separately.

Stoker-fired Boilers

In stoker-fired boilers the problems imposed by mineral matter in coal are threefold: Slagging in the fuel bed, formation of fly ash (which should rather read "entrained slag") and fouling. According to a general experience fouling is extremely heavy with high-rated

[1] The consequences of rapid heating will be discussed in greater detail in Part II of this paper which will appear in a later issue of COMBUSTION.

stoker-fired boilers, and by a statistical survey it was found that in Germany, for example, time of operation between shutdowns for cleaning was 3000 hr (maximum frequency value) (39).

The types of grates and stokers considered may include everything from hand-fired grates to underfeed stokers but the bulk of experience comes from traveling-grate stokers which are the most frequently used types in Europe. It may not be so well understood that the stoker is a high-temperature type furnace, with maximum temperatures usually exceeding 1500 C (3092 F) within the fuel bed although the residues come out as a resolidified solid. Another significant factor is the duration of the combustion process which keeps the fuel at high temperatures for a considerable period of time. The upper part of the fuel bed has strongly reducing atmosphere and best conditions for slagging appear at the "neutral zone" where highest temperatures coincide with the beginning of the reducing zone. Heat release rates within the fuel are calculated assuming a CO/CO_2 ratio according to Nicholl's experimental findings. Table V shows that these rates exceed those of pulverized coal-fired furnace by far and are of a similar order as those of cyclone furnaces, i.e., 600,000 Btu/cu ft-hr.

TABLE V—HEAT RELEASE IN THE FUEL BED OF A TRAVELING-GRATE STOKER

Burning rate, lb/sq ft-hr	20	30	40
Thickness of fuel bed, in.	4	6	8
Volume of the burning zone per sq ft grate area,* cu ft	0.166	0.25	0.333
Spec. burning rate with 67.5% C_{fix} in the coal, lb/cu ft-hr	81	81	81
CO/CO_2 ratio, vol. %	18/8	23/5.7	25.6/4.8
Heating value released, Btu/lb C	7,383	6,280	5,864
Heat released in the fuel bed, 10^6 Btu/cu ft-hr	0.60	0.51	0.47

* Effective length × width × half of the fuel bed thickness.

Gas producer practice has given an illustrative example of how residues of the same fuel and rate may be received as liquid slag in the slag-tap producer to clinker of any size wanted according to the steam/air ratio employed. Thus a conditioning of combustion air, as suggested earlier (40), could achieve similar results. Recirculation of flue gases, however, will bring about a more economic solution of the problem of fuel bed slagging.

Another trouble with caking coals is the excessive matting of the fuel bed. As a solution the following mode of operation is suggested using three main zones:

(1) A zone of devolatilization to avoid excessive caking by conveying hot flue gases through this zone, heating the fuel to a temperature just below its softening temperature,

(2) An ignition zone for rapid ignition by means of hot air of 300–400 C (570–750 F),

(3) A combustion zone operating with a mixture of flue gas and air keeping the oxygen content of the mixture at a value adapted to the nature of the coal ash.

The main features and advantages of such a combustion process (patent pending) is the use of extremely low excess air factors (1.05 to 1.10) and high air temperatures. A criterion of the "vitiated air" used for combustion is

$$K_v = \frac{N_2'}{O_2'} (H_2O' + 1.355\ CO_2')$$

N_2', O_2', H_2O', CO_2' referring to the composition of the moist flue gas/air mixture. Fig. 7 shows the surface temperature of carbon as a function of the index K_v and preheating temperature of the mixture. Full-scale experiments to demonstrate the feasibility of such a process are under way.

Fouling is greatly reduced by this method. Since the full-scale experiment at Delray Station of the Detroit Edison Co., it is well known that humidification of combustion air reduces deposit formation. Similar experiments in Germany with a variety of stokers and fuels have likewise been successful (41). More economic ways of humidification—other than the use of live or exhaust steam—have been suggested (42), and recycling of flue gas—if necessary cooled by water sprays—is equally effective and still more economical.

Reduction of fouling is also found to be the result of a reduced temperature which also reduces the volatilization of silica to unstable intermediate products such as SiO, SiS, SiS_2. Actually as already stated by Osann (43) at high enough temperature and at a sufficient length of time every component of the slag can be volatilized. This takes place in the following order: MgO, alkalies, FeO, CaO, SiO_2, Al_2O_3. Again one should consider the mineral constituents rather than the chemical entities. Moisture in the air assists to oxidize the unstable forms of silicon and so does a thorough mixture of gases, for example, by high-pressure secondary air supply. Both have been found to be helpful in reducing fouling tendencies.

The special case of salty brown coals has been studied by Rammler and Rudelt (44). Additives such as clay have proved quite successful in slowing down the rapid build-up of deposits whereas sand had the opposite effect.

Pulverized Coal Furnaces

Combustion temperatures of the pulverized-coal fur-

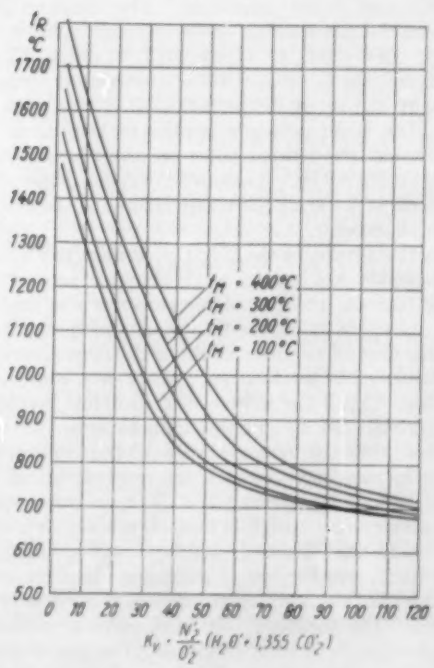


Fig. 7—Carbon surface temperature (C) on combustion with mixtures of air, flue gas and water vapor as a function of the index K_V and the temperature of the mixture

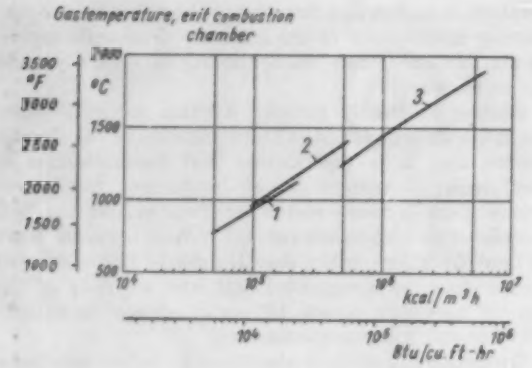


Fig. 8—Temperature of gases leaving the combustion chamber of clean (1), semi-slagged (2) and fully slagged surfaces (3) as a function of the rate of heat release (p. c.) firing

nace differs from the stoker-fired furnace. It is lower and the time during which a particle stays at high temperature is extremely short. The rapid rate of heating—3 to 5 powers faster than in any technological test—converts the mineral content of a single coal particle into a hollow sphere of slag within a fraction of a second. The most important point is to offer enough cooling surfaces to have the entrained slag particles cooled below their softening temperature or even below the softening temperature of any sublimed material deposited at the surface of such particles. The larger the unit size of a boiler is, the more difficult it is to slash the gas temperature down by radiation, and additional surfaces, platen surfaces, are required to succeed. Hence, it is mostly a question of the rate of heat release and low rates will warrant a trouble-free operation. The temperatures required of the gas leaving the combustion chamber are between 1000–1100 C (1832–2012 F) with harmless slags, 900–1000 C (1652–1832 F) with more dangerous long slags and at or below 800 C (1472 F) with salty coals. The same principle applies to brown-coal fired furnaces, but the temperatures are even lower, at 800–850 C (1472-1562 F). Lenkewitz (45) has demonstrated the success of lowering gas temperatures to the exit combustion chamber.

With the advent of the slag-tap furnace in its various types from the wet bottom single-chamber furnace to the cyclone furnace, the rise of temperature was first compensated by shortening the time of combustion and of the residence time of particles in the high-temperature zone. Cleanliness of boiler heating surface was improved to some degree until the influence of complete combustion was overbalanced by higher temperatures. It is well recognized that the increased rates of heat release in the cyclone furnace have created unexpected serious problems of deposit formation (46). Various improvements of cleaning methods with boilers on stream such as soot blowers and shot cleaning, developments of the cyclone design itself, and the use of additives—in some cases—have remedied the teething troubles of these new types of furnaces. The scrubbing action of unburnt carbon was found specifically helpful in keeping the size of deposits down.

The correlation of gas temperatures leaving combustion chambers and rate of heat release requires the extension of existing formulas to the case of a partially or fully slagged furnace wall. Two suggestions have been made (2). The Hudson-Orrok formula as modified by Reid, Cohen, and Corey may be expanded to

$$\mu\,(\%) = \frac{100}{1 + f_v\, C A \sqrt{Q}} \cdot f_k$$

where:

μ = furnace heat-absorption efficiency, per cent
f_v = factor indicating the degree of slagging
C = constant (0.123 with "clean" surfaces)
A = pounds of wet flue gas at furnace outlet per kB heat available in furnace
Q = heat available in furnace, kB per hour and square foot projected radiant heating surface
kB = 10^3 Btu
f_k = 1.34 − 0.017 (v), factor of coal type, a function of vol. matter (*maf*), applying to volatile matter content <20%. f_k = 1 when volatile matter ≧ 20 per cent.

Results of measurements with a partially slagged furnace (conical wet bottom type) by Noetzlin (47) show a fairly good agreement with this formula within ±3 per cent.

A second method of equally good result is based on the formula by Konakow (48) which is modified by two more factors for slagging and type of fuel. Fig. 8 shows the calculated relationship of three types of furnaces as a function of rate of heat release: (1) a clean furnace, dry bottom type, (2) a partially slagged furnace, wet bottom type and (3) a fully slagged furnace, slag-tap or cyclone type.

As a result of laboratory investigation, field experience, and calculation it may be concluded that any unnecessary excess of temperature over what is required to operate a slagging furnace should be avoided to ease the

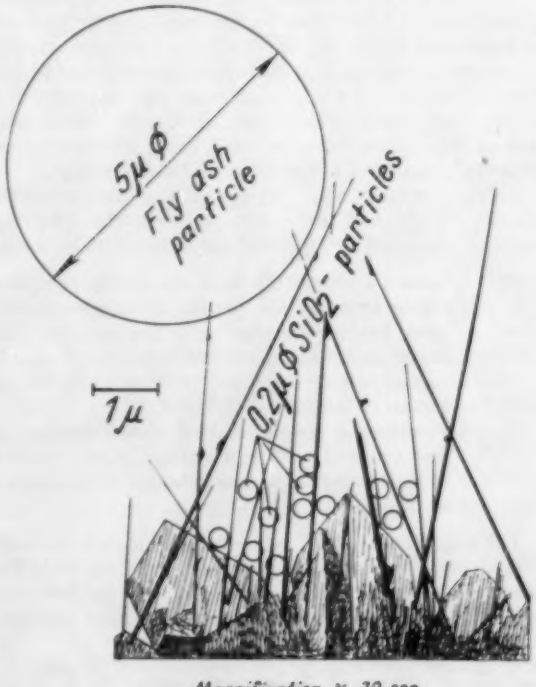


Fig. 9—Surface of iron oxide (after Pfefferkorn) with SiO_2 particles of 0.2μ diameter and a fly ash particle of 5μ for comparison

problems of deposit formation and to decrease the frequency of boiler outages.

Fouling of Heating Surfaces

Besides the nature, size and temperature of solid particles and the constituents of the flue gas, the state and temperature of the heating surface itself greatly affects the buildup of deposits.

As far as size is concerned, flue gas will carry large amounts of solids of submicroscopical size. Sublimation products, identified as little spheres of SiO_2, have been measured in the electronic microscope to have an average diameter of 0.2 micron. Such particles represent a considerable part of the inner layer of bonded deposits. Sulfate formation is likely to take place; SO_3 formation is not a prerequisite for such reactions since sulfates may be formed through the stage of sulfites by reaction of alkali chloride with SO_2. Fletcher and Gibson have clearly demonstrated this reaction by tracer method (49).

What makes the particle travel to the wall and stick there? A study of deposit formation by Rumpf has discussed various possibilities (50). Thermodiffusion and electrostatic forces have been suggested since tremendous voltage (200 to 3500 v) of pulverized coal in a bunker have been measured by Schäff (51). Temperature is certainly an important factor. Its influence on fritting and sintering is well known from powder metallurgy. Afterburning of only traces of carbon monoxide will heavily increase surface temperatures and induce stronger bondage. The catalytic action of steel surfaces has been demonstrated by experiments of Véron and Dumortier (52). Combustion starts at 150 C (302 F) and is completed at 300–375 C (572–707 F).

The surface of oxidized steel is not to be considered as covered by a smooth film but oxide crystals will grow out of the surface extremely fine needles like the leaves of grass. Fig. 9 is reproduced after an electronic microscope image of ferric oxide by Pfefferkorn (53); particles of SiO_2 of 0.2 micron and a rather small particle of commonly produced fly ash (5 micron ϕ) are sketched into this pattern. These monocrystal needles exert very strong adhesion forces (54). It can well be conceived that even the external submicroscopical structure of the surface offers a good start to deposit formation by mechanically collecting such particles of sublimation products. The absence of oxidized surfaces explains the "immunity" of new boiler tubes and the effect of smoothing the surface by graphite or similar coatings. It is generally agreed that deposit formation requires a continued effort of research for the full understanding and for the complete control of boiler operation even under adverse conditions.

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Central-Station Piping Trends*

By FRANK A. RITCHINGS† and SABIN CROCKER‡

Ebasco Services, Inc.

The trend of central-station development to larger units for higher pressures and temperatures, and frequently with cross-over piping incidental to the reheat cycle, has added to the complexity of piping procurement problems. Conditions have always been rather tight in this field and difficulties have increased as specified sizes steadily progressed to larger diameters and heavier walls. Procurement has become again a cause for concern with the steel industry operating at full capacity. The authors deem it pertinent to review how far the available diameters and wall thicknesses of seamless pipe go toward meeting actual central-station requirements, and to consider substituted kinds of pipe.

PROCUREMENT of seamless pipe has always been a difficult problem for the utility industry because of the reluctance of seamless pipe mills to add more manufacturing equipment for catering to an industry requiring a wide variety of carbon and alloy-steel products but only in relatively small amounts of any item for a given job. During World War II and the Korean situation procurement became critical and could again.

Under these circumstances it seems pertinent to review how far the available diameters and wall thicknesses of seamless pipe go toward meeting actual central station requirements and to consider what other kinds of pipe can be advantageously substituted where deficiencies exist. In analyzing the situation consideration needs to be given to factors such as suitability for the service, available lengths, relative costs, promptness of delivery and willingness of the manufacturer to accept small orders. In view of the present predominant interest in carbon and low-alloy ferritic steels for central-station piping the scope of this paper is limited to them and does not include austenitic steels.

Principal Features of Processes and Products

A brief description of the principal features of the different processes and products available is needed for consideration, together with the data on available diameters, wall thicknesses and lengths for the respective articles in Table I. Fig. 1 gives graphical presentation of the wall thicknesses of the three principal varieties of pipe as required to suit two typical service conditions.

Seamless

The term "seamless" is commonly used in piping-trade vernacular to denote pipe made from solid billets that are pierced and rolled into pipe on a Mannesmann or Pilger mill. Before these processes were developed, "seamless" pipe was made from circular plates in a hydraulic press by pushing the plates through successively smaller dies with a round-nose ram, eventually cutting off the closed end. This process, known as cupping and drawing, is still used to some extent; the product is often referred to as "cupped-and-drawn" pipe to distinguish it from the Mannesmann and Pilger varieties of "seamless" pipe. Several American steel companies have produced one or another of these varieties of "seamless" pipe to a limited extent but the ranges of diameters, wall thicknesses and lengths offered are by no means adequate to cover present-day central-station requirements.

Mannesmann or Pilger mills available in the United States for piercing and rolling seamless pipe in light to medium wall for other commercial purposes are incapable of producing anything heavier than Schedule 160 except in a few small sizes and, in fact, do not keep all the dies and mandrels needed for producing a full line of Schedule 160 or even a full line of some of the lighter schedules. So far American seamless-mill people have declined to spend the money needed for installing the piercing and rolling equipment required for producing pipe in a full line of sizes, in weights up to and including Schedule 160, on the grounds that the volume of business would not warrant the expense. One pipe mill, however, offers "cupped-and-drawn" pipe made by the original seamless method in a considerable variety of diameters and wall thicknesses. This process has shortcomings in that available lengths are short and the surface finish, particularly with alloy-steel materials, is not so smooth as with other methods. Hence the fabricators and users of large diameter and/or heavy-wall pipe have had to augment the supply by turning to other sources.

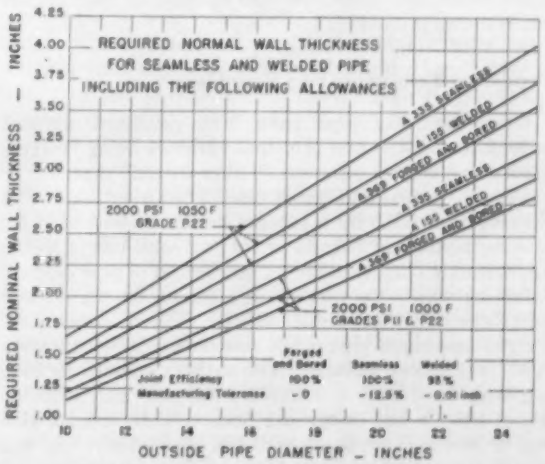

Fig. 1—Graphical presentation of the properties of three differently fabricated pipes as they apply to two typical services

* Presented before the American Power Conference, sponsored by the Illinois Institute of Technology, March 21–23, 1956.
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TABLE I—PIPE SIZES AVAILABLE FOR CENTRAL-STATION SERVICE AS MANUFACTURED BY PROCESSES SHOWN
(Diameters, Wall Thicknesses, Lengths)

Outside Diameter, In.	Nominal Wall Thickness Range, In. Minimum		Maximum	Available Lengths, Ft[1] Seamless: Pierced & Rolled	Seamless: Cupped & Drawn	Seamless: Hollow Forged	Forged & Bored[2]	Welded Seam: Plate Pipe Shop A	Welded Seam: Plate Pipe Shop B	Welded Seam: Boiler Manufacturer A[3]	Welded Seam: Boiler Manufacturer B[4]
10.75	0.188	to	1.563	35–44	...	...	...	...	...	...	...
	0.750		1.563	35–44	...	18–22	35	...	...	...	...
	1.000		1.500	...	...	...	35	...	...	...	20
	1.000		4.000	...	...	...	35	...	...	...	...
11.75	0.500		1.000	...	19–21	...	...	...	...	...	...
		1.625		...	9	...	...	...	...	...	...
	1.000		1.625	...	...	...	35	...	...	...	20
	0.750		2.125	...	...	18–22	35	...	...	...	...
	1.000		4.500	...	...	...	35	...	...	...	...
12.75	0.219		1.313	35–44	20	...	...	...	...	...	...
	1.500		1.875	...	10–12	...	35	...	...	...	...
	0.500		2.000	...	...	...	...	...	...	15	...
	0.750		2.000	...	...	15–22	35	...	...	...	20
	1.000		5.000	...	...	...	35	...	...	...	...
14.00	0.250		0.937	44	...	...	...	...	...	...	...
	0.438		1.062	...	17–21	...	...	...	...	...	...
	1.250		1.406	...	14–15	...	35	...	...	...	...
	2.000		2.676	...	11–13	...	35	...	...	...	...
	0.312		0.750	...	...	...	...	10–14	14	...	...
	0.500		2.000	...	...	...	...	...	...	15	...
	0.750		2.500	...	...	15–22	35	...	...	...	22–38
	1.000		5.500	...	...	...	35	...	...	...	...
16.00	0.250		1.218	28–44	14–20	...	...	10–20	12–18	...	...
	1.437		2.250	...	8–12	...	35	...	...	...	...
	0.750		2.500	...	...	15–22	35	...	...	15	...
	1.000		2.750	...	...	...	35	...	...	...	24–40
	1.000		6.500	...	...	...	35	...	...	...	...
18.00	0.250		1.156	25–39	12–21	...	...	...	...	...	...
	1.343		2.500	...	9–11	...	...	...	...	...	...
	0.312		1.500	...	...	...	...	20	18	...	...
	0.750		2.750	...	...	...	35	...	...	15	...
	1.000		3.000	...	...	14–22	35	...	...	...	25–40
	1.000		7.500	...	...	...	35	...	...	...	...
20.000	0.250		1.281	25–43	15–17	...	...	...	...	...	...
	0.375		1.500	...	...	...	...	20	18–20	...	...
	1.125		3.500	...	...	12–22	30	...	...	...	...
	0.875		3.000	...	...	...	30	...	...	15	25–40
	1.000		8.500	...	...	...	30	...	...	...	...
24.000	0.375		0.937	22–41	...	...	...	...	...	...	...
	0.375		1.219	...	10–11	...	...	...	...	...	...
	0.375		1.625	...	...	...	...	20	18–20	...	...
	1.313		4.250	...	...	12–22	30	...	...	...	...
	1.000		3.000	...	...	...	30	...	...	15	25–40
	1.000		10.500	...	...	...	30	...	...	...	...
30.000	0.375		1.375	...	...	...	...	20	...	...	...
	0.375		2.250	...	...	...	...	...	15–20	...	...
	2.750		4.750	...	...	8–20	20	...	...	...	30
	1.000		13.500	...	...	...	20	...	...	...	...

[1] Values shown are maximum length ranges in reverse order for the wall-thickness ranges tabulated at left, viz. the shorter lengths go with the heavier walls.
[2] Actual lengths will vary somewhat between the several manufacturers of forged and bored pipe. Lengths up to 50 feet in diameters up to 22 inches have been reported.
[3] Made with one longitudinal seam.
[4] Made in halves with two longitudinal seams.

Seamless pipe as made in accordance with ASTM Specifications A53, A106, A335 etc. has a manufacturing tolerance on wall thickness of plus or minus 12½ per cent. Available diameters, wall thicknesses and lengths are as shown in Table I.

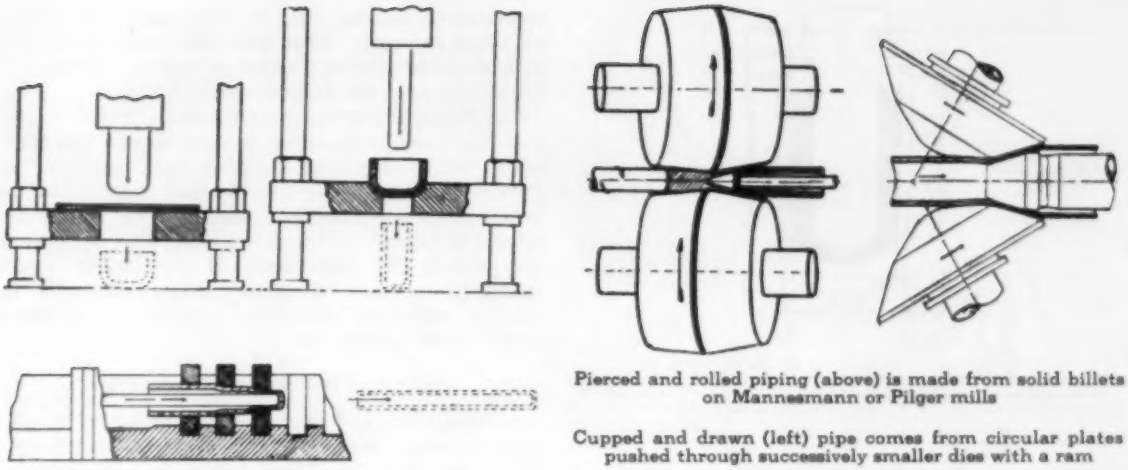
Products Equivalent to Seamless

Other kinds of pipe have been produced without welded seams, the two principal varieties being "forged, turned and bored" pipe and "hollow-forged" pipe.

Forged, turned and bored pipe is furnished to ASTM Specification A369 by a process similar to that used for making naval gun barrels by forging solid billets to the approximate outside diameter and length of pipe desired, following which the forgings are turned on the outside and bored on the inside to the desired dimensions. Forged-and-bored pipe is not new although Specification A369 is of recent vintage. The authors know of its having been used with a 12,000-kw topping unit installed about 1930 in the Deepwater Station of Houston Lighting & Power Company where the main-steam line was designed for 1350 psig, 825 F using flanged joints.

Solid billets for making large diameter forged-and-bored pipe may weigh as much as 25 tons before turning and boring. Pipe lengths of 30 to 35 ft are possible except in diameters over 24 in. where presently available ingot weights tend to reduce lengths so that 30 in. diameter pipe cannot be produced in lengths over 20 ft. Actual lengths will vary somewhat between the several manufacturers of this kind of pipe. Lengths up to 50 ft in diameters up to 22 in. have been reported. Wall thicknesses can be machined to anything desired, subject to having a minimum inside diameter of 2½ in. or so needed for passing a boring bar through the pipe. Wall thicknesses possible with this limitation are shown in Table I. Close tolerances are possible because the product is machined inside and out to specified dimensions. Commercial manufacturing practice as covered in ASTM Specification A369 provides that the wall thickness measured on inspection shall not vary over that specified by more than 1/8 in. There shall be no variation under the specified thickness nor over the specified inside diameter. This kind of pipe can be obtained from several heavy-forging manufacturers.

"Hollow-forging" is the name given by one of the large boiler manufacturers to a process recently introduced in its own shop for making waterwall and superheater headers. The equipment also is suited for producing large-diameter heavy-wall pipe which is offered



Pierced and rolled piping (above) is made from solid billets on Mannesmann or Pilger mills

Cupped and drawn (left) pipe comes from circular plates pushed through successively smaller dies with a ram

for sale to others. The principal pieces of equipment used are a heavy hydraulic press for piercing ingots, and a drawbench. In this process the ingots are pierced in a vertical hydraulic press which forges them into hollow blooms having one closed end. The blooms are then placed in a horizontal drawbench and formed into pipe by pushing them through a series of ring dies by means of an internal mandrel which bears against the closed end. After cooling, straightening and cutting off the closed end, hollow-forged pipe is machined on the outside to specified tolerances. Internal dimensions are maintained within the desired limits by the mandrel in the action of drawing. "Hollow-forged" pipe is produced within the same manufacturing tolerances as "seamless," for which the wall-thickness variation is plus or minus $12^1/_2$ per cent.

A description of "hollow forging" will be found in *Mechanical Engineering* for October 1952, pages 818 to 820. Available pipe diameters, wall thicknesses and lengths are given in Table I. This process is particularly suited to making seamless pipe in small quantities and with heavy walls whereas the Mannesmann seamless process is better suited to making large quantities of light to medium-wall pipe. European and Japanese pipe made by a similar process also is available in about the same diameters, wall thicknesses and lengths.

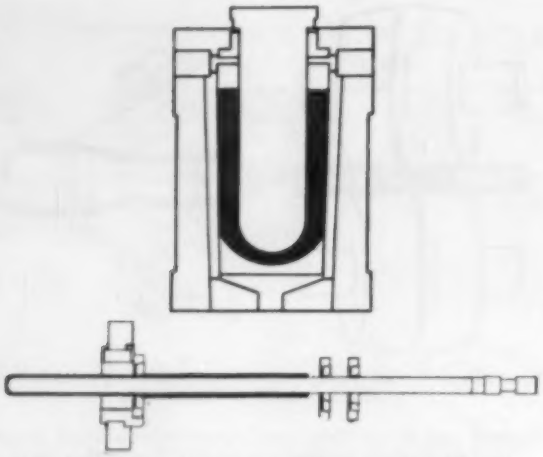
Basically, "hollow forging" is just another way of producing seamless pipe (or headers) according to specifications such as ASTM A53, A106 or A335. In so far as the consumer is concerned, the chief differences are: (1) that the manufacturer has tooled up to produce a greater variety of wall thickness than other American pipe mills are equipped to provide; and (2) that the equipment is adapted to quick switching of dies and hence is suitable for filling orders of lesser footage, and possibly more promptly, than other seamless mills.

Centrifugally-cast steel pipe has been under development for over ten years but is not yet commercially available for use in central stations. The well-known success of centrifugally-cast cast-iron pipe has led to the extension of this process to cylindrical articles made of carbon and alloy steels as well as non-ferrous metals. Hollow shafts have been made in this manner, and other cylindrical articles such as drums, sleeves and the like. Some centrifugally-cast steel pipe has been made for experimental purposes and specifications for the product have been tentatively discussed. It is understood that the results of certain recent fabrication and service tests are about due for publication. This process seems to offer possibilities and it is to be hoped that the results of the current experimental work will be encouraging. Whether centrifugally-cast steel pipe can be used successfully in the as-cast condition or whether the material will have to be rolled or extruded or otherwise processed to refine the as-cast structure remains to be seen. Information so far available indicates that cylinders can be centrifugally cast in lengths up to 16 ft with a wall thickness of 2 in. up.

Electric-Fusion-Welded Pipe

Electric-fusion-welded steel pipe for high-temperature and/or high-pressure power plant service is made to ASTM Specification A155. Plate material is formed into cylinders on bending rolls, or by other means, following which operation the longitudinal seam is fusion welded by an electric process that deposits filler metal. Class 1 pipe is heat treated and radiographed, whereas Class 2 is not radiographed and the requirements for heat treatment depend on the wall thickness and composition of the plate. Fusion-welded pipe has a wall thickness within the tolerance of the specification to which the plate is bought, usually minus 0.01 in., plus about 3 to 5 per cent.

Electric-welded plate pipe and headers are not a new product. ASTM Specification A155 for "Electric-Welded Steel Pipe for High-Temperature Service" was first published as tentative in 1934 and adopted as standard in 1936. This specification has been referenced through the years by the American Standard Code for Pressure Piping. Although Specification A155 is not referenced in the ASME Boiler Construction Code, the omission is considered a technicality arising from the fact that the welding is not conducted under Boiler Code inspection. Similar headers or pipe can be manufactured under Boiler Code rules and inspection; in fact the A155 Class 1 product with the welded seam radiographed does qualify under the Boiler Code if inspected according



Hollow-forged piping process employs ingots pierced in a vertical hydraulic press and the blooms placed in a horizontal draw bench and pushed through ring dies

to its rules. The Boiler Code has permitted welded drums for some 25 years.

A155 welded-seam pipe has been used to some extent for "hot" and "cold" reheat piping in central stations in diameters of 16 to 24 in. or so, and wall thicknesses of the order of $^1/_2$ to $1^1/_2$ in. This light to medium wall material is fabricated in plate pipe shops and, for plate thicknesses that can be formed on their equipment, they do a very creditable job. Available diameters, wall thickness and lengths as furnished by two of the principal sources of this product are shown in Table I. As stated in the scope of A155 this pipe "shall be suitable for bending, flanging (van stoning), corrugating and similar forming operations." Actually such forming operations severely tax the properties of any pipe and the fact that considerable quantities of A155 pipe have been successfully hot bent for use in reheat piping is an encouraging indication of its quality. But aside from the high quality of this particular product, any welded-seam pipe has inherent disadvantages for high-temperature piping applications in comparison with the seamless variety as discussed hereinafter.

Since 1950 two of the principal boiler manufacturers have started making the equivalent of A155 pipe for use as furnace-wall and superheater headers, and more recently have offered their product for sale as pipe. This material ranges in size from 10.75 to 30 in. O.D. and is on the medium to heavy-wall side as shown in Table I. The principal systems where these thicknesses might be used in central station piping are main steam and boiler feed. Obviously the criteria for acceptability here are even more rigorous than those obtaining for reheat piping.

The difference in thickness range of the products produced by these boiler manufacturers as distinguished from the plate-pipe fabricators is due to the fact that the boiler people form heavy plate into cylindrical shape between dies in a hydraulic press whereas the pipe fabricators form light to medium plate into cylindrical shape over rolls. One manufacturer presses its plate into a complete cylinder which requires only one welded seam, whereas the other manufacturer presses its plate into half cylinders which require two welded seams. Once formed, the processes of welding, heat treating and radiographing are much the same. Thus these two variations of A155 pipe are complementary although they do overlap to a certain extent in the medium-weight field.

What these boiler manufacturers seem to have to offer with A155 pipe is the ability to form heavier wall thicknesses by pressing than the plate-pipe fabricators can form by rolling. While their product is acceptable for drums and headers, its suitability for severe service conditions in central-station piping is open to question on the grounds that any variety of welded-seam pipe is inferior to seamless for several reasons as discussed below, at least until satisfactory performance is demonstrated through actual use.

Features of Welded Longitudinal Seams

Welded-seam pipe differs from any variety of seamless pipe, including "hollow-forged" and "forged-and-bored," in several respects. There are both advantage and disadvantage characteristics of the different types, but in all cases the presence of a welded longitudinal seam introduces certain problems that are non-existent with the welded line joints (girth seams) commonly used in assembling all varieties of steel pipe. These problems are accentuated at elevated temperatures or where appreciable thermal expansion takes place in the piping system.

Distinctions Between Line Joints and Seams

There is a basic relationship that a longitudinal seam is subjected to twice the stress due to internal fluid pressure that a line joint has to support. Hence the importance that there be no lack of soundness in the welding of longitudinal seams. There are several other reasons, some only theoretical perhaps, why a pipe line consisting of welded-seam pipe might be considered not the equal to one containing only welded line joints.

Line joints often can be located where they are not subjected to the maximum bending moment due to thermal expansion, although this possibility diminishes as pipe lengths decrease. Also where a line joint can be located in a straight run of pipe it operates under more favorable conditions than does a longitudinal seam which runs through bends as well. Any curved pipe such as a bend is subjected to severe localized bending stresses due to expansive movement which do not exist in straight pipe. These localized stresses result from the tendency for the circular cross section of the pipe in a bend to flatten (become oval) during flexure, thus causing additional stresses to act on the seam.

Where pipe is bent during fabrication, it might be reasoned on the strength of past experience that seamless pipe is preferable to any kind of welded-seam pipe on the grounds that either hot or cold bending subjects the seam to unequal strains which might cause cracking or even split the weld. How true this is for high-grade electric-weld pipe needs to be weighed after more experience is had with this product.

Under conditions where there is a tendency toward graphitization in the heat-affected area adjacent to a weld the difficulty of effecting repairs by cutting out the graphitized area or by solution treatment might be greater in a longitudinal welded seam than in a girth joint. Also there would be more weld to repair than if the pipe were seamless. Were the whole piping system

Formed and welded piping starts out as plate material; formed into cylinders on bending rolls and then the longitudinal seam is fusion welded

to be replaced, however, these considerations would not be a factor.

In view of the foregoing it will be of interest to await the results of further experience with welded-seam pipe in central-station service. Pending longer use of the product in the form of bent pipe in reheat lines, consideration might be given to trying it out in straight runs of main steam lines with forged or seamless welding elbows instead of pipe bends. Another way to avoid placing welded-seam pipe in bends subject to expansive movement is to have a floating superheater outlet header on a boiler with the turbine placed so as to need only a short run of straight pipe between it and the superheater outlet. This has been done in at least two installations during the past 15 years. What is saved in the cost of piping, however, tends to be offset by increased boiler costs.

With drums or headers the existence of a welded longitudinal seam is not a problem, principally because they are used as straight cylinders and neither bent during fabrication nor flexed in curved form in use. Attention is called, however, to paragraph P104 (e) of the ASME Power Boiler Code which reads "The design of welded drums and shells shall be such that the bending stresses are not brought directly upon a welded joint." This prohibition is even more pertinent with a curved member like a pipe bend than it is with a straight cylinder such as a drum or header. Nevertheless with headers and drums it would seem advisable to see that pipe nozzles, which might transmit bending moments, are located where they do not straddle welded seams.

Joint Efficiency Applied to All Welded Seams

The joint efficiencies applicable to welded seams in drums or headers provided in the Boiler Code, and to ASTM Specification A155 for "Electric-Fusion-Welded Steel Pipe for High-Temperature Service" in the Piping Code ASA B31.1—1955 are as follows:

ASME Power Boiler Code—Section I—1952

Paragraph P-102—"In applying the rules in paragraph P-180 (containing the formula for computing the wall thickness of drums or headers), a welded joint efficiency of 95 per cent may be used provided all weld reinforcement is removed substantially flush with the surface of the plate. (In order to get a more clean cut radiograph.) Otherwise a joint efficiency of not to exceed 90 per cent shall be used."

Code for Pressure Piping, ASA B31.1—1955

Footnote 3 of Table 2a entitled Allowable Stresses

TABLE II—DIMENSIONS AND COST RATIOS FOR COMPARABLE MAIN-STEAM PIPE AS MADE BY DIFFERENT PROCESSES*

Outside Diameter, In.	Kind of Pipe → ASTM Specification No.	Seamless: Cupped & Drawn A335	Seamless: Hollow Forged A335	Seamless: Forged & Bored A369	Welded Seam: One Seam Variety A155	Welded Seam: Two Seam Variety A155
12.75	Average length	18′3″	21′0″	35′9″	14′9″	19′3″
	Number of lengths	14	12	7	17	13
	Number of welds included	15	13	8	18	14
	Minimum wall, in.	1.575	1.575	1.575	1.645	1.645
	Nominal wall, in.	1.813	1.813	1.575	1.656	1.656
	Cost ratio to least expensive	1.26	1.00	1.65	1.33	1.60
14.00	Average length	15′0″	21′0″	35′9″	14′9″	19′3″
	Number of lengths	17	12	7	17	13
	Number of welds included	18	13	8	18	14
	Minimum wall, in.	1.720	1.720	1.720	1.795	1.795
	Nominal wall, in.	2.000	2.000	1.720	1.813	1.813
	Cost ratio to least expensive	1.36	1.00	1.64	1.32	1.57
18.00	Average length	8′9″	21′0″	35′9″	14′9″	25′0″
	Number of lengths	29	12	7	17	10
	Number of welds included	30	13	8	18	11
	Minimum wall, in.	2.195	2.195	2.195	2.290	2.290
	Nominal wall, in.	2.500	2.500	2.195	2.313	2.313
	Cost ratio to least expensive	1.50	1.00	1.72	1.16	1.05

* This is a spot comparison for three different sizes of pipe based on the following conditions:
1. A 250-ft run of main-steam piping designed for 2015 psig 1015 F.
2. Material in all cases is Grade P11 ferritic steel containing 1¼ per cent chromium and ½ per cent molybdenum.
3. Cost ratios are based on estimates which include cost of pipe at the mill with a 12½ per cent fabricators handling charge, plus the cost of making the number of line welds needed for assembling the respective number of lengths of pipe into a 250 ft continuous line.
4. *Not* included are freight, hangers, insulation and erection costs.

TABLE III—DIMENSIONS AND COST RATIOS FOR COMPARABLE HOT-REHEAT PIPE AS MADE BY DIFFERENT PROCESSES*

Outside Diameter, In.	Kind of Pipe	Seamless-ASTM A335 Pierced & Rolled	Seamless-ASTM A335 Hollow Forged	Welded Seam-ASTM A155 Plate Pipe Shop A	Plate Pipe Shop B	Boiler Manufacturer One Seam	Boiler Manufacturer Two Seam
16.00	Average length	26′0″	23′0″	19′4″	19′4″	14′9″	31′3″
	No. of lengths	10	11	13	13	17	8
	Number of welds included	11	12	14	14	18	9
	Minimum wall, in.	0.702	0.792	0.731	0.731	0.731	0.731
	Nominal wall, in.	0.843	0.843	0.750	0.750	0.750	0.750
	Cost ratio to least expensive	1.05	1.12	1.66	1.00	1.41	1.45
24.00	Average length	....	23′0″	19′4″	18′0″	14′9″	35′9″
	Number of lengths	....	11	13	14	17	7
	Number of welds included	....	12	14	15	18	8
	Minimum wall, in.	....	1.021	1.069	1.069	1.069	1.069
	Nominal wall, in.	....	1.218	1.079	1.079	1.079	1.079
	Cost ratio to least expensive	....	1.27	1.41	1.00	1.25	1.19

* This is a spot comparison for two different sizes of pipe based on the following conditions:
1. A 250-ft run of hot-reheat piping designed for 600 psig 1015 F.
2. Material in all cases is Grade P11 ferritic steel containing 1¼ per cent chromium and ½ per cent molybdenum.
3. Cost ratios are based on estimates which include cost of pipe at the mill with a 12½ per cent fabricators handling charge, plus the cost of making the number of line welds needed for assembling the respective number of lengths of pipe into a 250 ft continuous line.
4. *Not* included are freight, hangers, insulation and erection costs.

for Pipe in Power Piping Systems—"The allowable stresses (S-values) tabulated are for A155 Class 2 pipe on the basis of 90 per cent joint efficiency. For Class 1 pipe which is heat treated and radiographed, these stresses may be increased by the ratio of 95 divided by 90."

Acceptability Aside from Seam

Fusion-welded pipe made from plate has certain inherent differences from seamless pipe with respect to manufacturing tolerances on wall thickness, presence of surface defects such as slivers, scores, scratches and abrasions, susceptibility to hidden defects such as laminations and slag inclusions. Except for wall thickness tolerances these differences are qualitative rather than quantitative. The following general observations may be of interest.

Wall Thickness Tolerance

Seamless pipe has a "nominal" wall thickness with a plus or minus 12½ per cent manufacturing tolerance. "Hollow-forged" pipe is made within the usual seamless tolerances as stated in ASTM Specifications A106, A335 etc.

Forged-and-bored pipe is machined to specified dimensions. The wall thickness measured on inspection shall not vary over that specified by more than ⅛ in. There shall be no variation under the specified thickness nor over the specified inside diameter.

Fusion-welded pipe has a wall thickness within the tolerance of the specification to which the plate is bought, usually minus 0.01 in., plus about 3 to 5 per cent.

Laminations and Slag Inclusions

The extent of laminations and slag inclusions experienced with either seamless or plate pipe depends largely on how generously the ingots or billets are cropped before rolling. Where laminations come to the end of seamless pipe or to the edge of plate material they can be readily detected and the material rejected or cropped as circumstances warrant. Plate material has the advantage of having more edge material open for inspection than has seamless pipe. Further examination of either product can be carried out by ultrasonic testing where agreed, although plate and pipe mills will not accept rejection on this score at their expense. Experience so far with plate seems to indicate more trouble with hidden laminations than is experienced with seamless. The cross rolling and other precautions taken in manufacturing firebox-quality plate are said to result in less laminations than are to be expected with flange-quality plate.

Surface Defects

Seamless pipe in general seems more susceptible to acquiring surface defects in the process of piercing and rolling than is experienced in rolling plate. Hence seamless pipe specifications contain more extensive requirements than specification A155 does to govern the extent of surface defects that will be accepted and their repair by chipping and welding where permitted. Plate material has a further advantage in that it can be inspected and repaired on both sides before making into pipe, whereas repair to seamless pipe is pretty much limited to the outside. Whether "hollow-forged" is better or worse than other seamless pipe in this respect remains to be seen after more experience with the product.

Relative Cost

The subject of cost is one which can be discussed here only in relative terms. Generally speaking, the cost of most varieties of seamless pipe is not far different from that of pipe formed from plate and having an electric fusion-welded seam that is radiographed. Both kinds contain about the same amount of steel, and the cost of piercing and drawing seamless from a solid billet seems to come somewhere near matching the cost of forming plate into cylindrical form, welding the seam and radiographing it.

Forged, turned and bored pipe, however, is manufactured by an inherently wasteful process. After a solid billet is forged to approximately the desired diameter and length, much of the interior of the billet is reduced to scrap in the form of chips from the boring operation. The thinner the desired wall thickness, the greater the wastage and hence the higher the relative cost.

In comparing costs for different kinds of pipe it is necessary to take into account the maximum lengths obtainable by the respective processes inasmuch as shorter lengths require more line-joint welds during fabrication and erection. Maximum lengths available by the different processes are shown in Table I. Where a range of available lengths is shown opposite a range of wall thicknesses for a particular product, the shorter lengths go with the heavier walls, and vice-versa.

The relative costs shown in Tables II and III for main steam and reheat piping respectively were derived for typical 250-ft runs of pipe based on recent costs of pipe at the manufacturer's mill or shop, plus allowance for

line-joint welds made in the shop or field for assembling the respective number of lengths into a 250-ft run. The service conditions chosen for Table II correspond to the main-steam line for a large turbine having throttle conditions of 1800 psig and 1000 F; those for Table III to the hot reheat piping for the same unit operating at about 600 psig and 1000 F. In comparing these cost ratios two things should be borne in mind: (1) This is only a spot comparison for a few sizes of pipe of one material; and (2) cost ratios will change from time to time depending on demand for the respective products.

Conclusions

Cost differences and procurement difficulties experienced in obtaining some varieties of seamless (including forged-and-bored) pipe needed for central station use point the need for encouraging all promising new sources of supply and for giving full consideration to other reasonably acceptable kinds of pipe. The following possible uses of electric-fusion-welded pipe are suggested as being reasonably promising for further consideration:

1. Reheat or similar weight piping, possibly using seamless or forged elbows instead of pipe bends where expansion stresses are particularly severe.
2. High-pressure boiler-feed piping beyond the scope of seamless pipe (except forged-and-bored), using forged fittings instead of pipe bends.
3. High-pressure, high-temperature main-steam lines where the pipe is placed in straight runs not subject to high bending moments.

These suggested uses are inclined toward the cautious side until further experience is had with the product. If fabrication and service reports continue to indicate satisfactory performance in severely stressed locations such as pipe bends, and if other forming operations prove successful, more confidence in its use will naturally ensue.

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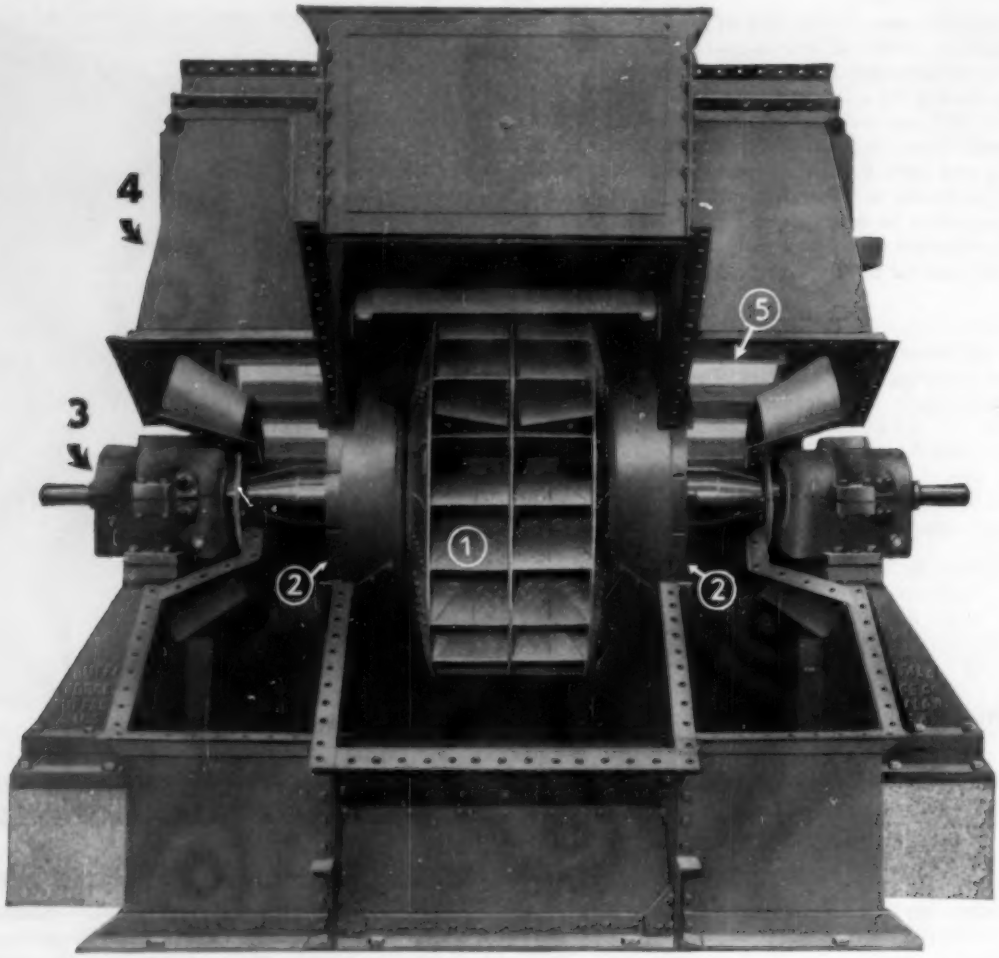

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American Power Conference in Review—I

THE eighteenth annual meeting of the American Power Conference held at the Sherman Hotel in Chicago, March 21–23, enjoyed a registration of some 2700, insuring excellent attendance at all technical sessions.

R. S. Stevenson, president of the Allis-Chalmers Mfg. Co., shared the major assignment of the opening session with **Clarence A. Davis,** undersecretary of the U. S. Department of Interior. In Mr. Stevenson's opinion the U.S.A. attained its position of power from more than the accidents of geography, racial mixtures or advantages of natural resources—that something more was the ability to put mechanical horsepower to work to magnify our efforts. He expressed a grave concern over the shortage of engineers and the failure up to the moment to correct the situation at the high school level.

Secretary Davis spoke of the role of government in the development of the nation's power potential in a talk entitled, "Our National Resources of Energy Potentials." He favors less government operation of power producing facilities with more concentration on the regulatory phases as the proper role for government participation in the development of power potentials.

Harlee Branch, Jr., president of Georgia Power Co. and this year's president of the Edison Electric Institute, served as the speaker for the opening luncheon. As his topic he chose the subject "Power and Politics" to point out a misgiving he has that the electric industry still is treated as a political stepchild by certain appointive and elective officials in our government. This is a condition that has no justification in the light of the industry's accomplishments. A most significant statement made by Mr. Branch was: "Since World War II the free enterprise electric industry has carried on the greatest expansion program in its history. It has not only kept abreast of America's phenomenal postwar industrial expansion but has literally set the pace for it." Mr. Branch closed out his address by referring to the admonition of Thomas A. Edison, shortly before his death, to the electric power industry: "Be courageous—be as brave as your fathers before you. Have faith. Go forward."

Brigadier General Herbert D. Vogel, chairman of the board, Tennessee Valley Authority, in his luncheon address, "Some Operational Aspects of the TVA's Large Integrated Power System," expressed the conviction that the natural advantages accruing to a system such as TVA employing both steam and hydro-generated power are such as to produce a marked effect on rates. Freedom from interest, Federal taxes, and the need to make a profit contribute in addition to these advantages. But the operational statistics the General advanced were most interesting to his listeners.

For example, the Edison Electric Institute reported in the calendar year 1954 private utilities produced at an average of 4983 kwh per kw of capacity for steam plants and 4914 kwh per kw for hydro units and an overall average of 4938 kwh per kw. The TVA had an average that same year, overall, of 6325 kwh per kw and for its steam plants 8637 kwh per kw, resulting in a utilization factor of 98 per cent.

In fiscal year 1955 the EEI reported a 60 per cent load factor for the total utility industry against the TVA's 75 per cent figure. Of course the atomic plants served by TVA receive their power at a 98 per cent load factor.

John T. Rettaliata, president, Illinois Institute of Technology, was the feature speaker at the All Engineers Dinner. He chose as his topic a report on the continued shortage of engineers. Insufficient enrollments and a high ratio of withdrawals was advanced by Rettaliata as the major reasons for the failure of colleges to supply more trained engineering graduates. A study completed three years ago by the Educational Testing Service that covered 101 engineering colleges and more than 13,000 freshman entrants showed that 56 per cent withdrew or had been dropped. The problem, Rettaliata claimed, was at the high school level where preparation is often inadequate.

The final luncheon was addressed by **John Jirgal,** chairman of the group on power, generation and distribution, of the second Hoover Commission. His talk dealt with "The Federal Role in the Socialization of Power". He approached his subject by opening with comparisons between the years 1933 and 1953 of the position of public power in the country's supply and the position of the Federal government in this power supply picture. Mr. Jirgal then went into detail on the various items tending to produce an unfavorable situation as regards private versus public power groups. He pointed out that the Hoover Commission Task Group, of which he was chairman, had recommended local interests, public or private, should from now on develop its own power growth requirements and not the Federal government, and that as soon as feasible existing Federal power facilities should be disposed of through sale or lease to local interests. Certain interim steps could be taken pending this sale. In the field of atomic energy as soon as national security permits the Federal government should follow the above principle of local interests controlling the development and the ownership of facilities required for this new energy source.

Air Pollution

As might be expected with a heavy power industry audience the controversial subject of air pollution was scheduled and given a three-paper treatment.

Dr. L. C. McCabe, now president of Resources Research, Inc., talked on the "Significance of Sulfur Dioxide As an Air Contaminant." Much of his paper was devoted to reports and accounts on the dangerous effects of SO_2 in the air. There were three principal conclusions Dr. McCabe drew: (1) The most sensitive indication of SO_2 concentration is the level at which damage to plants occur and this is usually from 0.2 to 0.5 ppm.

Next in point of sensitivity is the odor of SO_2, usually at strengths of about 3 ppm. The last sensitive indication is the one set by health authorities as the tolerable limit for industrial workers of 10 ppm. (2) Treatment of stack gases bearing SO_2 by dilute acids is worthy of more study. If the stack gas concentration is of the magnitude of 0.5 ppm and there is a strong local market for sulfur it may prove economical today to wash out the SO_2. (3) The problems of synergism, that is, the effect of other gases, elements, temperature conditions, and similar environmental factors, on the difficulties produced by varying quantities of SO_2 gases is still pretty much an unknown field and requires considerable data before conclusions can be made.

F. S. Mallette, executive secretary, Committee on Air Pollution Controls, ASME commented on the "Implications of Current Air Pollution Legislation." There is considerable evidence, Mr. Mallette stated, to show that today the overall problem of air pollution is demonstrably worse. The causes of this increase in pollution are, briefly, the tremendous growth of population in our cities, due to both migration and birth-rate; the enormous increase in numbers of automobiles, trucks, and buses and their resulting exhaust gases; the incineration of vast amounts of rubbish; the combustion, both domestic and industrial, of terrific volumes of fuels; and the great expansion of manufacturing processes of all kinds, many resulting in new and, as yet, uncontrolled effluents. The atmospheric sewer is backing up and, like a swarming bacterial colony, the economy is beginning to suffer from the accumulation of its own wastes.

To alleviate this problem of modern civilization, local government is turning to a good old-fashioned remedy—the law—to legislate air pollution out of existence.

The average smoke-control ordinance is relatively simple, providing for the prohibition of black smoke of a given density (usually #2 Ringelmann) and forbidding the emission of fly ash of a certain concentration (usually not exceeding 0.95 lb per 1000 lb of gases).

There is a trend, however, toward broader municipal air-pollution-control ordinances, based on the Los Angeles County Ordinance as a model which prohibits the emission of all toxic and/or nuisance effluents, with even specific levels for certain gases, such as sulfur dioxide. For industry and business enterprises in general, all of this air-pollution-control activity means restrictive legislation and ultimate capital expenditures for abatement equipment. Nothing is so distressing as the vast sums which have been wasted by industry on useless control equipment purchased hurriedly because of pressure from a community where the situation has become emotional and desperate.

Research, not legislation, is the basic answer to the problem of air pollution in the opinion of **W. L. Faith,** vice president and chief engineer, Air Pollution Foundation. Unless legislation is based on knowledge of the facts the harm done may override any good that will result. Among the by-products of the technology that has brought us comfort and leisure is air pollution. Obviously, the logical approach toward solving the problem must be by ascertaining the facts and developing the remedies—in broad terms, research.

The greatest quantities of contaminants in the air are the result of incomplete combustion or use of imperfect fuels, for which the entire community is responsible, in the author's opinion. Roughly half of the fuel burned in large communities is burned in transportation equipment, private homes, and other nonindustrial units.

Central Station Steam Generators

A two-paper session on the general subject of central station steam generators presented extremely interesting information on improvements and advances in the conventional steam boiler to meet (1) the various combined gas turbine-steam turbine supercharged boiler cycles (2) the very high capacity steam demands for units already on the drafting board as well as the even higher ones planned for the not too distant future.

In the first, "Supercharged Boiler Design, Development and Application" by **Ernest L. Daman** and **Robert J. Zoschak,** the supercharged boiler cycle was described as one where a steam boiler operates in conjunction with a gas turbine so that the combustion air for the boiler comes from a compressor driven by a gas turbine which, in turn, is driven by the expansion of the combustion gases leaving the boiler.

There are several reasons for interest in the super charged cycle. (1) Foremost among these is a 5 to 9 per cent improvement in plant heat rate over that of a conventional cycle of equivalent rating and steam conditions. (2) Greatly reduced boiler size and weight, allowing shop assembly of relatively high capacity units and considerable installed space reduction with attendant cost saving. (3) Improved load response and reduced starting time. (4) Considerable saving in piping due to the possibility of grouping equipment closer.

Actually there are two types of supercharged cycles—the self-sustaining cycle or the power cycle.

The self-sustaining cycle, of particular interest to marine and small land installations, is similar to the original Velox system where the gas turbine operating in conjunction with the boiler drives only the compressor which furnishes air required for combustion without developing a net power output.

The power cycle differs from the self-sustaining cycle in that the gas turbine also generates electrical power. This generation of part of the plant output in the gas turbine at high gas temperatures improves the cycle efficiency, and carries a definite appeal for large generating stations.

The supercharged boiler, like the conventional boiler, will vary in arrangement and design concepts for different sizes, fuels, applications, and steam and gas side conditions. Its radiant furnace has a potentially high heat absorption directly related to the combustion gas pressure (from 3–7 atmospheres) since the ratio of the furnace volume required for complete burning of the fuel in a supercharged boiler to that required in a conventional boiler is equal to the inverse ratio of the absolute pressures in the two furnaces being compared.

Although absorption rates up to 450,000 Btu per hr-ft^2 projected furnace envelope have been realized in some units, economic and arrangement considerations in the authors' opinion, suggest limiting the furnace absorptions to the order of 200,000 Btu per hr-ft^2 projected furnace envelope.

Considerable simplification in the mechanical design of supercharged boilers can be realized by taking advantage of the once-through principle on the steam side. This will eliminate the many riser and downcomer pipes and their connections through the pressure shell.

The second paper on this session, "High Capacity—Two-Furnace Boilers" by **E. M. Powell,** Combustion Engineering, Inc., has been printed in its entirely on pp. 42 of this issue. In brief Mr. Powell commented on the remarkable progress in boiler design within the last decade. Several curves he produced showed very graphically the developments of this period in steaming capacity, steam temperatures and operating pressures. Certain of the data revealed thereby indicated that the steaming size of boiler units in the central station field will go to 200 to 250 mw by 1960 with the largest units from 400 to 500 mw.

Similarly throttle pressure which has been climbing at a rate of 73 psi per year for the average reheat boiler will reach the level of 2300 to 2400 psi by 1960. As boiler pressures go beyond this level the once-through design will be imperative.

Steam temperatures have experienced average yearly increases of 9 degrees per year. By 1960 the average central station boiler unit will be operating at 1060 F. Today the highest temperature in operation is 1100 F with one unit already under design for 1200 F. The average 1960 boiler will have one stage of reheat at 1060 F or slightly lower.

Today's twin furnaces, Mr. Powell points out, have brought the power industry safely to the levels anticipated for 1960 with units successfully running at 1800 to 2500 psi, 1000–1050 F and 250 mw.

Flyash and Slag

The problems generated within the furnaces of the power boilers today include among them slag and flyash. The presence of these by-products represents a two-horned difficulty. If they stay within the furnace they build up an insulating coat on the heat exchange surfaces and cut down on the heat transfer. Further if these fireside deposits form as slag they present still another problem in their physical removal since they cling tenaciously to metal surfaces.

Harris Thompson, National Aluminate Corp., in a paper "Chemical Treatment for Fireside Deposit Prevention in Coal-Fired Boilers," attempted to outline the problem and to emphasize the progress in the use of chemical treatment toward reducing slagging difficulties in specific cases. One very frequent occurrence of such slagging develops in boilers fired at rating far above the original design and burning coals of a quality never called for. Improved mechanical equipment such as steam and air soot blowers have helped as well as some of the experimental techniques such as cleaning slagged surfaces with steel or wooden pellets.

Scientific application of chemicals for fireside deposit prevention is a relatively new branch of power plant chemistry. Much excellent research has been done and much more needs to be done. Work has been done with oil firing as well as coal firing, and in gas turbine as well as boiler furnaces. It has been with various specific objectives, for example, (1) prevention of pyrosulfate enamel deposit and corrosion of radiant furnace wall tubes, (2) prevention of deposit fouling of furnace and superheater tubes, and (3) prevention of airheater corrosion and deposits. It has produced important basic information.

Among the various solutions suggested are: (1) use of premium fuel, (2) blending fuels, (3) redesign of existing furnaces or boilers, (4) installation of new soot blowers or other cleaning equipment, (5) improved control of burner operation, (6) balancing individual burner output, and (7) application of chemical treatment.

Chemical treatment costs for slag prevention may be from four to ten cents per ton of coal at present, depending on the severity of the problem. These costs are within the usable range in many plants, depending on what and how severe their troubles are.

Actual field tests have shown success with chemical treatment for fireside deposit prevention, especially where trouble is due to high alkali content in the coal ash. Success has also been experienced in preventing slag in paper mill recovery boilers where the deposits are primarily alkali. The costs of chemical treatment are within economic reach of many plants and would be expected to decrease in the future. The author supplied an excellent bibliography on the subject at hand as part of his paper.

Robert B. Freston, Commonwealth Edison Co., in his paper, "Flyash and Slag Materials of Value," discussed the marketability of these nuisance by-products in modern boilers. So far cyclone flyash, for example, is not marketable as collected. The slag is comparable with that from wet bottom pulverized-fuel furnaces and is similarly marketable.

Slag as a marketable commodity, though, has had a less dramatic development than flyash. Its most extensive use has been in the manufacture of black roofing granules. Also it has had some use as an anti-skid material for streets, highways and for jet plane runways. The most promising large volume use to date, is in a lime-flyash-slag pavement base course material called Poz-O-Pac. In this form, as employed in the Chicago area slag represents 75 parts, flyash 25, lime, four or five and all mixed with enough water to dampen it.

Flyash, on the other hand, has enjoyed considerable study. The Chicago Commonwealth sample is not a cement by itself, but it does have excellent pozzolanic action and has the property, as do other pozzolans, of uniting with lime to form very hard and durable cementitious materials. Flyash is a man-made pozzolan far more uniform in particles size and quality than the natural material, and the fused silica spheres are its most important constituent.

High Temperature—High Pressure Design

Two sessions were devoted to the complex field of high temperature-high pressure design. The papers presented dealt variously with supercritical pressure problems as they applied particularly to turbines and feedwater heaters and to the companion high temperature difficulties of the steam services and piping.

"Metallurgical Requirements of Metals for Steam

Service Above 1000 F" was the subject of **F. B. Foley** and **R. M. Wilson, Jr.,** of International Nickel Co. The philosophy of design for steam power equipment, said these authors, comes from the ASME Power and Pressure Vessel Code which outlines the basis for establishing design stresses in Par. A-150 of Section I and in Appendix P for ferrous materials and Appendix Q for non-ferrous materials, of Section VIII of that Code. These methods of establishing design stresses are similar, though they differ slightly in their mechanics of operation.

It is necessary first to determine a metal's short-time tensile and yield strengths at room temperature and at succeeding higher temperature increments over the useful temperature range of the alloy. These values can then be plotted, stress vs. temperature. For the nonferrous metals, these two curves are discounted somewhat to bring them in line with the minimum tensile strength and minimum yield strength of the material specification. This discounting is not always done with ferrous alloys.

The authors presented plots of design stress vs. temperature for a few of the alloys known to be useful at elevated temperatures. The Boiler Code is now taking advantage of all the inherent characteristics of the present alloys. By specifying a grain size no finer than ASTM No. 6 and by being sure that the material is annealed by specifying a solution anneal after all fabricating except welding, a higher creep and rupture strength will result.

The Boiler Code is also investigating the possibility of establishing design stresses on a more liberal basis. As yet there are no concrete improvements but some results should be possible without sacrifice of safety.

The inadequacy of present conventional alloys to meet the increasing temperature and pressure requirements of the steam power industry was clearly shown by the authors in data presented in tabular form. Under the present ASME Boiler Code the permissible stresses for Stainless Steel Types 347 and 316 allow a reasonable, (about 1.6 in.,) wall thickness for a 5 in. I.D. pipe carrying 5000 psi steam pressure at 1100 F and 2.4 to 3.6 in. wall for 1200 F service. Beyond these temperatures the wall thickness becomes prohibitive.

To enable the use of pipe having a wall thickness of the order of $1^1/_2$ in. will require the use of alloys having greater high temperature strength than any which have been given consideration by the ASME Power and Pressure Vessel Code.

John M. West, Foster Wheeler Corp., limited his paper "Design Aspects of High Pressure Feedwater Heaters" to the effect of the higher pressure and temperatures and larger unit sizes on feedwater heaters. Feedwater heaters for such service usually have a desuperheating zone, drain cooler zone, and condensing zone incorporated in a U-tube type unit.

At the present time, in fact, designs have been prepared up to 4700 psi tube-side pressure. Present thinking regarding supercritical pressures indicates the use of a booster pump between the condensate and the boiler feed pumps. With this arrangement, the highest extraction pressure heaters are located between the two pumps and operate in the 1500–2500 psi range. There is some thought given to cycles in which at least one heater is designed to operate on the boiler feed pump discharge pressure. Turbine driven pumps operating at constant discharge pressure over the capacity range, will permit heater design pressures only slightly above operating pressures.

The effective surface for single heaters seems to have reached a temporary limit of about 10,000 sq. ft. These are economical to build with available lengths of tubing.

Many new units are designed with twin high pressure heaters, thereby reducing the unit size. Because of possible advantages, such as (1) savings on valves and piping and (2) more flexible operation, the trend toward twin heaters will undoubtedly continue. The total cost of twin heaters more nearly approaches the single heater costs as the total surface increases, and in the 10,000 sq ft range, the difference in cost is almost negligible.

The paper "Central-Station Piping Trends" by **Frank A. Ritchings** and **Sabin Crocker,** Ebasco Services, Inc., reviewed how far the available diameters and wall thicknesses of carbon and low-alloy ferritic steel seamless pipe go toward meeting actual central-station requirements, and further, what other kinds of pipe can be advantageously substituted where deficiencies exist. In analyzing the situation, the authors took into consideration factors such as suitability for the service, available lengths, relative cost, promptness of delivery and willingness of the manufacturer to accept small orders. This paper in its entirety appears in this issue on pp. 55.

The paper opened with a description of the principal features of the different processes and products available together with the data on available diameters, wall thicknesses and lengths for the respective pipe.

Cost differences and procurement difficulties experienced in obtaining some varieties of seamless (including forged-and-bored) pipe needed for central station use point the need in the opinion of the authors for encouraging all promising new sources of supply and for giving full consideration to other reasonably acceptable kinds of pipe. The following possible uses of electric-fusion-welded pipe are suggested as being reasonably promising for further consideration:

1. Reheat or similar weight piping, possibly using seamless or forged elbows instead of pipe bends where expansion stresses are particularly severe.
2. High-pressure boiler-feed piping beyond the scope of seamless pipe (except forged-and-bored), using forged fittings instead of pipe bends.
3. High-pressure high-temperature main-steam lines where the pipe is placed in straight runs not subject to high bending moments.

R. M. Curran and **A. W. Rankin,** General Electric Co., speaking on "Application of High-Temperature Metals to Modern Large Steam Turbines," pointed out that many of the nation's major production and defense industries are faced with the problems of increasing pressures and/or temperatures, and frequently at levels considerably above those now under consideration in power-generation organizations, so that there is no dearth of new alloy compositions which can be considered for steam-turbine

construction. Specifically, it is relatively easy to select an alloy, or many alloys, which, in laboratory tests, have the requisite high temperature strength, but it is a problem of great complexity to select an alloy which, in addition to the requisite high temperature strength, will also have the characteristics needed for the particular requirements of steam-turbine construction and operation. Their paper discussed these particular and peculiar requirements and their effect on alloy selection for steam-turbine construction.

The first distinguishing characteristic in steam-turbine construction is the expected long life of the equipment beyond 100,000 to 300,000 hours of operation. Such long operating times at elevated temperature pose problems with respect to both the stress levels which may be safely imposed and the metallurgical changes which may take place in the material and affect other important properties as well as strength.

The recent development of the Larson-Miller parameter of time and temperature against a metal's rupture strength, however, has simplified the problem of estimating rupture life as a function of stress considerably, and has enabled conservative evaluation of long-time strength to be made on the basis of tests of only a few hundred hours' duration. Through these parameter evaluations, it has been possible to utilize the jet-engine industry's tests at shorter times and higher temperatures to evaluate the usefulness of super-alloys for steam turbine applications.

At the elevated temperatures encountered in steam-turbine construction metallurgical changes in addition to surface phenomena can take place within the metal structure with profound effects on material properties. These changes result from the fact that in the processing of metals there is frequently insufficient time for a state of thermodynamic equilibrium to be achieved. Such metals, inherently unstable, experience a driving force during service tending to move the atoms within the metal structure to achieve the equilibrium states. Since the mobility of atoms is much greater at higher temperatures, materials can proceed in the direction of equilibrium at finite rates. Accumulating and interpreting data to determine the effect of metallurgical instability on the properties of materials after long-time service is a much more difficult problem than that of estimating strength levels.

In the size of the equipment involved, the steam turbine differs most markedly from other users of high temperature metals, and this characteristic renders development in this field both time-consuming and costly. Of the various elements concerned the turbine rotors are both the most critical components and the ones with the heaviest sections. The requirement of thermal stability at operating temperature for such rotors is generally accepted at this time, and one of the most important tests during manufacture is the heat-indication tests. It is sufficient at this time to merely point out that a bending at speed and temperature of only a few thousandths of an inch will result in an unacceptable level of vibration.

The question of sufficient ductility depends greatly on the degree of notch restraint and the specific operating conditions. Almost all high temperature alloys gradually lose rupture ductility with time at temperature and in this respect steam-turbine applications are most severe because of the extremely long operating lives involved. The major difficulty in ductility evaluations is that no ductility parameter, which permits trading time for temperature, is available similar to the Larson-Miller rupture parameter. Accordingly, quantitative evaluations of long-time ductility must be based on extrapolation of creep and rupture tests of one year's duration or more, coupled with the five-year tests which are made on specific materials committed to production.

Motors and Generators

Two widely different forms of rotating equipment in modern power stations were discussed in a single session. The one dealt with the economics of generating capacity replacement and the second with the major auxiliary drives in the power plant.

On the first of these **L. B. Vesconte,** Sargent & Lundy, presented a paper entitled "Economics of Replacement of Generator Capacity" and the second, **A. E. Beardmore,** General Electric Co., discussed "Major Auxiliary Drive Motors in Steam-Electric Power Plants."

"Economics of Replacement of Generator Capacity" by L. B. LeVesconte, Sargent & Lundy, stressed that one problem continually confronting utility engineers and executives is how to determine when to add new generating capacity, especially since these decisions and commitments must be made two or three years before the capacity is needed. Closely associated with this problem is the question of where to locate it, what size units and what characteristics of efficiency to provide and when to retire old units.

The question of when to add generating capacity in Mr. LeVesconte's opinion is primarily a function of the relations between maximum load and generating capability. The load is not a quantity to be measured, but rather, the load that is forecast for several years in advance, with definite figures to apply for the years selected. In considering if the total generating capability is adequate for the load, it is necessary to consider what reserve should be maintained in excess of the maximum load and this reserve should be based on the probability of the loss of generating facilities.

The location of the new generating capacity will be a compromise between the needs of the load and the practical sites available. Considering only electrical problems, it would be best to have it near the load. However, there are more inflexible requirements such as fuel supply at a low cost, water for cooling or for makeup in cooling towers, and a location remote from residential areas. Usually, a realistic and practical review of these conditions will narrow the choice down to two or three locations.

The unit rating should be as large as practicable because this can be installed at a lower cost per kilowatt and will have a lower cost for fuel and operation. However, if it is too large for the system it may be too much of a burden to finance it, and the greater carrying charges may exceed the gain due to better economy.

Mr. Beardmore expressed the belief that in approach-

ing the drive for plant auxiliaries keep in mind the fundamental idea that all the user is after is something to provide the correct torque and speed characteristics. Then the problem becomes one of determining how this requirement can be met most reliably and economically. Here the reference to economics includes first cost and also maintenance over a period of years.

To select a motor for any drive it is necessary to know a great deal about the torque requirements of the driven machine. The ideal condition is one where there is available a speed-torque curve showing the requirements of the driven equipment during the accelerating period, the inertia of the driven equipment effective at motor shaft speed, and also information on the variation in load during normal operation. If there are overloads, the amount and duration of such overloads should be known. If the equipment, such, for example, as an ash sluice pump, is to be started frequently, the duty cycle should be known. Accurate knowledge of these conditions will assist in selecting an adequate motor and yet prevent over-motoring, thus saving the user money.

One point that should be kept in mind by those making the application, and also by the users, is the fact that repeat starts with a short interval of time between starts is a much more severe duty on the motor than continuous operation at full load. All the motors normally used in power stations are designed for full voltage starting. The stator winding is adequately braced to stand the current inrush due to full voltage starting and, contrary to what many expect, starting on full voltage results in less motor heating than starting on reduced voltage and transferring to full voltage at some point during the accelerating cycle. Further it is essential to keep the voltage at the motor terminals as nearly balanced as reasonably possible and at the proper value.

In specifying the voltage of the motor to be used on a power system, it should be kept in mind that the voltage of the distribution system should be slightly higher than the motor voltage. This is necessary in order to make allowance for transformer regulation and for a voltage drop in the circuit from the bus to the motor, in order to maintain rated voltage at the motor terminals.

In order to keep the stress on the motors and driven equipment to a minimum when transferring from one source of auxiliary power to another, a live transfer—that is, paralleling the two sources of power—is preferred. In such transfers the motors are never deenergized and there are no unusual torques imposed on the driven equipment.

Fuel Purchasing

The energy source behind the increase in per capita use of electric energy—from 1590 kw in 1945 to 3310 by 1955—was the subject of a session devoted to fuels.

Julian E. Tobey, Appalachian Coals, Inc., brought to light in his paper, "Effects of Preparation and Other Factors on the Economics of Coal Buying," the fact that the revolutionary changes that have occurred with respect to fuel use have demanded a change in the practices and habits of buying and selling. However, advancement here has been very slow in forthcoming. The utilities themselves have been so occupied in the dynamic expansion of their capacity, in the urgent problems of financing, construction, and in securing and training operating crews to man the new plants that many have either not had the time or felt any urgency to give but superficial consideration to long-range fuel requirements.

During most of the last decade, coal has also been in a falling market pricewise and this plus the temporary over-supply situation probably had a lulling effect. In a falling market there is always a tendency to put too great emphasis on spot buying or short-term commitments and give too little attention to the long-range outlook. Furthermore, too great emphasis probably was placed on the fact that modern boiler units such as have been installed since the war, and which account for about half the present capacity, are much more flexible than their predecessors and the general opinion that they could burn "just anything."

Some estimates were made by utility representatives that the slag problem was costing the utility industry a hundred million dollars a year and this was equivalent to a dollar a ton as the industry was burning about a hundred million tons of coal. Reports were also made on the cost of these boiler outages as amounting to from five to seven thousand dollars per day, for a million pound unit, and this did not include the actual maintenance costs. It represented only the replacement power cost or the difference between shutting down a modern unit having a heat rate of 1 lb or less per kwhr and starting up standby equipment in its place which had a heat rate of say 2 lb per kwhr. In other words, this would double the coal consumption and the coal bill with respect to this arrangement.

To make a proper evaluation of fuel costs, such factors as fixed charged on standby equipment; power replacement cost resulting from boiler outages or from boilers operating below the maximum stability, as well as operating and maintenance costs, must be included. While all the factors involved in incremental costs cannot be thoroughly analyzed, a number of items of importance in making such an analysis were included by the author. They included: standby facilities, coal handling, ash handling, pulverizers, boilers and sources of supply.

The second paper in this session, "Impact of Freight Rates on the Distribution of Coal" by **A. W. Vogtle,** De Bardeleben Coal Corp., opened with the statement that the salvation of the interdependent coal and railroad industries would appear to depend on cooperation based on realistic and practical view of mutual problems.

The expanded use of labor-saving machinery has reduced cost per ton of coal. The per man day output has increased from 6 tons in 1945 to 9 tons last year, and 16 tons—in step with the popular song—is an early goal.

Since 1948 there has been an advance of 30 per cent in the basic miners' wage, as well as an increase in the miners' Welfare Fund, combined total 78 cents per ton.

The f.o.b. mine price of coal, despite these wage increases, has been reduced from $4.99 per ton in 1948 to $4.82 per ton in 1954, reduction 17 cents per ton, national average.

In the railroad industry, however, there have been six major general increases in rail freight rates since World War II, despite railroad labor-saving modernization; and a seventh increase was made effective March

7. The rail freight rates on coal have been increased an average of 88 cents per ton in the postwar period, including the 15 cents advance of March 7.

It is crystal clear to those in the industry, according to Mr. Vogtle, in studying the impact of freight rates on the distribution of coal, that the continuing increase in freight rates is responsible for the major part of the diversion of industrial consumption to other fuels. and the railroads haul neither the unproduced coal nor the substitute fuels. Coal, in a herculean struggle to meet competition, has absorbed its own entire increase in labor costs of 78 cents per ton. But it is utterly beyond its capability to also absorb the increased rail freight charge of 88 cents per ton.

A compilation by 19 of the major utilities of Eastern United States reveals an average mine cost of coal in 1948 of $5.14 per ton; an average railroad transportation of $3.07 per ton; with relation of the transportation charge to mine price as 60 per cent. In 1955 the coal was $3.99, the transportation $3.64 and the percentage relation 91. That is, the percentage of the transportation charge to coal cost increased from 60 per cent in 1948 to 91 per cent in 1955.

Under the impact of increased rail rates on coal, the public utilities and other large industries have found various alternatives, viz.:

1. Transportation by water, truck, pipe-line, conveyor belts
2. Power plant location at mine mouth or on navigable water.
3. Use of oil and gas, with plants adapted to interchangeable use of fuels, changeover requiring only minutes.

The location of power plants on navigable inland waterways provide the twin advantage of ample water supply and low cost barge transportation. This trend is snowballing and is accompanied by development of riverside mines and mines reaching river ports by short rail haul for trans-shipment by barge. The 1955 participation in coal transportation with 1948 as index 100, is rail 86 and barge 122. This means that the flight of coal from the railroads is likewise a flight from the mines in coal fields dependent exclusively on rail transportation to the markets.

Power Plant Design

Three distinct areas of the industrial power supply picture were explored in an Industrial Power Plants session. The one paper dealt with an interchange of fuel and raw water from a nearby refinery to a power plant operated by a public utility system and designed for the refinery waste fuel in exchange for electric energy and steam. The second paper described a paper mill installation and the third a system of centralized control for a series of high and low pressure boilers serving a processing industry.

The first paper of the session, "The Linden Generating Station" by **F. P. Fairchild,** Public Service Electric & Gas Co., described the power plant, built and operated by a public utility to serve its neighboring industrial in this instance, an oil refinery. The design of Linden Generating Station is a rewarding change of approach to the problem of lowering operating costs of steam power plants because it is expected to achieve a substantial improvement in economy without an increase in steam conditions. None of the principles applied in this plant is new. However, the size of the equipment, the magnitude of the throttle and process flows and the high operating economy constitute a significant forward step in steam power plant engineering.

In the usual application of an extraction steam turbine-generator, the entire output of steam and electric energy goes to the same user, and the necessity of maintaining a balance between the two sometimes results in undesirable limitations in operation. At Linden, however, the steam goes to an oil refinery while the electric output goes to both the refinery and the Public Service system. This arrangement makes it possible to build a plant capable of generating highly economical non-condensing power in quantities much greater than the electric requirements of the refinery, which in this case, buys its electric service from Public Service in the same manner as other customers.

Basically, the construction of Linden Generating Station adjacent to the Bayway Refinery of the Esso Standard Oil Co. is a mutually advantageous combination of two industrial processes; namely, the processing of crude oil to refined petroleum products and the conversion of refinery residuals to electric energy. The refinery can use the generating station's low level heat energy effectively; and the generation station can make good use of the residuals of the refining processes.

The arrangement of three boilers supplying one turbine, which is usual today, was chosen with reliability of steam supply in mind. Two boilers are sufficient to operate the unit with full extraction flow from the turbine.

Throttle steam conditions of 2000 psig, and 1050 F were chosen for the first unit as a design compromise between reliability, cost, efficiency and optimum turbine design for the extraction of process steam. With three boilers, a steam turbine, and two turbine bypasses connected to a double steam header, it was desirable to avoid (1) the complications of reheating, and (2) the higher cost of a steam piping system with austenitic steel valves. Therefore the upper limit for the steam temperature was set to allow the use of ferritic steels. The throttle steam pressure was determined from the exhaust conditions necessary to satisfy the requirements of the refinery.

Before final agreement was reached for a contract covering the operating arrangement for the first unit, it became apparent that another unit would be required soon after the installation of the first unit, to meet the increasing demands of the Public Service electric system. Since the dependability of process steam supply had been designed into the first unit, the approach to the design of the second unit was more in the direction of the concepts used in other recent installations, i.e., high steam temperature, steam reheating and a single boiler for the turbine-generator.

The cost of operating the first unit will be relatively insensitive to fluctuations of fuel prices because the amount of exchanged fuel burned is large in respect to the total fuel required, and this makes it unlikely that solid fuel will be burned in the boilers of this unit. How-

ever, the plant is laid out with space for future installation of pulverized fuel equipment. In the case of the second unit, the proportion of exchanged fuel is smaller, and since the period of an assured supply of purchased fuel is shorter, it was decided to construct the boiler of the second unit in such manner that a minimum outage (about two weeks) would be involved in its conversion to pulverized fuel burning.

The three identical boilers of the first unit are of the radiant type, using small tubes, 2 and $2^1/_2$ in. outside diameter, with radiant platen superheaters, and steam washers. They are constructed for pressure firing without induced draft fans.

The boiler for the second unit is of the radiant type constructed for pressure firing without induced draft fans. In the boiler a relatively high proportion of the total heat generated is absorbed in the superheater and reheater. To facilitate the heat transfer, three distinctive design features are employed; (*a*) radiant platens, (*b*) two furnaces with differential, or bias, firing and (*c*) gas recirculation, not only at the control load, but also at full load.

The temperature of the high pressure steam is controlled by gas recirculation while differential firing controls the reheated steam temperature. Attemperation will be used to trim the high pressure steam temperature. When oil is being fired, the recirculated gas will be mixed with the combustion air and it will enter the furnace through the burners, which are suitable to burn pulverized fuel and gas as well as oil.

The turbine of the first unit is a record-breaking machine in at least two respects. The throttle steam flow of 2,800,000 lb per hour, which corresponds to a rating of 425,000 kw in a straight condensing, conventional reheat machine, will be the largest in the world when this unit commences operation in 1957. The rating of 225,000 kw will make it the largest double automatic extraction turbine ever built.

Throttle steam conditions for the first turbine-generator are 2000 psig and 1050 F. The maximum total extraction steam flows are 600,000 lb per hr at 750 psig and 1,000,000 lb per hr at 150 psig, although the sum of the two is limited to 1,150,000 lb per hr at any one time. The unit is designed to produce 225,000 kw output over the entire range from maximum to zero extraction.

Because of the unusually large throttle flow, the high pressure element has a double flow arrangement in which the extraction steam for process flows toward the generator, and the steam destined for the condenser flows toward the front standard. The double-flow arrangement of the high pressure element has three important advantages. First, splitting the high pressure steam path into two streams brings the steam flow per wheel within the range of current experience. Second, it avoids the necessity of designing control valves for flows of very large volume at the two extraction steam pressures; the control valves on the upper and lower halves of the low pressure extraction element have to pass a total flow of only 1,000,000 lb per hr of the 150 psig extraction steam at a pressure of 750 psig. Third, the opposing flows of steam minimize the changes in total turbine thrust due to variations in either electrical load or process steam extraction.

Unlike an ordinary industrial or public utility power plant which supplied electric power or steam, or both, to other users, a pulp mill power plant has several other functions to perform which are just as vital to the production of pulp as are the steam and power according to the opening remarks of **Edward J. Martin,** Procter & Gamble Co., in his paper, "Some Features of a Recently Constructed Pulp Mill Power Plant." By evaporation and burning, the Buckeye Cellulose Corp., Perry, Florida, has its plant get rid of all the black liquor made in the digesters, at a rate in excess of 200 tons per hour; reclaim most of the chemicals contained in the black liquor at a rate of $8^3/_4$ tons per hour; prepare new makeup chemicals (known as salt cake) for the process, at a rate of $1^3/_4$ tons per hour; and, burn in a bark boiler all the bark produced in the debarking operations at a rate of $22^1/_2$ tons per hour. With the exception of the bark burning operation, any serious interruption to these functions will reduce or stop the production of pulp.

The process of disposal of black liquor, recovery of chemicals, and preparation of makeup chemicals, known as the B&W Tomlinson Process, has been an operation separate and more or less remote from the power plant in most previously built pulp mills. At Foley, the whole chemical recovery system is a part of the power plant.

The largest single unit of the recovery system is the Babcock & Wilcox chemical recovery boiler, which is rated at 413 standard tons, and produces 220,000 lb of steam per hour as a by-product of the recovery operation. The boiler's physical size is not indicated by its actual steam output. If it were operated as a regular steam boiler, it would have a capacity of about 430,000 lb per hr.

The bark boiler is a two-drum, Type VU, Combustion Engineering bark and oil burning unit, having a steam generating capacity of 140,000 lb per hr, when burning the maximum rate of bark containing 50 per cent moisture. By firing oil at the same time an additional capacity of 20,000 lb per hr is obtained. When fired solely with fuel oil, the boiler has a steam capacity of 200,00 lb per hr.

Sand impregnated in the bark during the years of tree growth has been the cause of serious troubles in the operation of many previously built bark burning boilers. It has quickly eroded the pressure parts of the boiler and it has fused on the grates, making combustion inefficient, and ash removal very difficult. The experience with this boiler shows practically no erosive action on the tubes, and the removal of the sand and ash is easily accomplished.

The remainder of the steam load, not supplied by the chemical recovery and bark boilers, is generated by two Babcock & Wilcox, FH type, two-drum 175,000 lb per hr capacity, boilers, oil-fired and so set that pulverized coal or gas can be burned should these fuels become economical.

Two General Electric, non-condensing, automatic extraction, turbo-generators, one 7500 kw and one 6000 kw capacity, pass out steam at 150 psi pressure, and exhaust at 50 psi pressure. A third turbo-generator, a Westinghouse 1500 kw condensing unit, is motivated by 150 psi pressure, 650 F temperature steam and is used regularly. This unit helps in balancing the steam system, and furnishes power when needed during periods the pulp mill is not operating.

The third paper on the design session, "Experience with Centralized Control of a Three-Unit Boiler Installation" by **G. E. Hoff, D. S. Hagen** and **L. C. Laird,** Corn Products Refining Co., recounted the evaluation of centralized control of a multi-unit boiler installation in light of experience gained from localized control. In a short period of five years, the Corn Products Refining Co. lived through a transition at its Argo Plant which allowed comparison of operation under three different operating conditions.

In 1949, the Company installed two 250,000 lb per hr pulverizer feed boilers operating at 650 psig and 700 F. These two new units supplied steam for two new 60-cycle, 7500-kw extraction type, non-condensing turbo-generators and worked in conjunction with twenty-five 160 psig, 360 F boilers which supplied the 25-cycle turbo-generators and process heat requirements. Certain experiences had been realized in the operation of these two high pressure units which made it desirable to re-examine the operating requirements when the plans were made for the addition of a third high pressure boiler.

A simultaneous study of the requirements for operation of a chemical process and the operation of these boilers showed some striking similarities. In general, as the authors see it, a boiler can be viewed as a chemical process in which air, coal, chemical and water are supplied in the correct amounts to produce steam with by-products of ash, flue gas and blowdown. Experience which had been obtained from the design of two corn sugar refinery control centers was sufficient to show that the one with a graphical representation of the process and logical arrangement of the instruments in the control center was an extremely desirable aid in times of emergency to even the most experienced operation. The advantages seemed to be: (1) substantial labor savings; (2) reduced floor space required for gage boards; (3) reduced amount of time necessary to train operators; (4) arrangement to give the operator more complete understanding of the boiler operation, thereby increasing his feeling of security and confidence; (5) better coordination of boiler capacities during times of emergency; (6) place automatic soot blowing operations under one operator; (7) allow provisions for operator comfort with reduced noise and temperature.

There appeared to be a logical grouping of the instruments required in the control center. The first group—which must be within the reach of the operator at all times—were put on consoles. The second group—instruments which must be constantly viewed by the operator—were put on a graphic panel. The third group—instruments which need not be manipulated by or constantly viewed by the operator such as the soot blower controls, various integrators and recordings for operating records—were placed in panel sections on either side of a window behind the operator.

Operation of many low pressure boilers, with the power house adjacent, certainly had its advantages for handling variable steam demands. However, after the first step in the modernization program, the operation of a complete system for steam and electrical power generation, which included many low pressure boilers, two high pressure units and stations for both 25- and 60-cycle power generation, presented a number of problems. To make the high and low pressure boiler units compatible for process purposes, it was necessary to maintain temperature control in two pressure reducing and desuperheating stations. Although the high pressure boilers were best suited for handling the variable steam demands, the high pressure boiler operator equipped only with gage boards was essentially on local control. During the construction of the third high pressure boiler and the control room, preparation was made for operation from a centralized station.

Boiler Feed Pumps

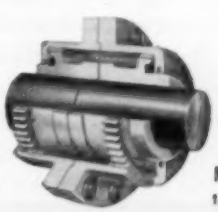
The continued upward trend to higher pressure, higher capacity steam generators and turbines has prompted a number of investigations of the fundamental boiler cycle and the components employed in that cycle. As a result the boiler feed pump, its performance and its choice of drive have been under review.

Lewis L. Dawson, Cameron Pump Div., Ingersoll-Rand Co., led off a three-paper session on boiler feed pumps with "Special Problems on Boiler Feed Pump Installations." He set right to work with a discussion of the feed pump motor-bearing problems that led to the development of limited-end float couplings. On multi-stage centrifugal pump drivers the end surfaces of the motor bearings were being wiped. The answer seemed to increase the standard motor end float and decrease the standard coupling end play. All in all, the author stated, it makes a better job, however, if the motor bearings are adequate to carry the required endwise load and some discriminating customers were reported as insisting on adequate thrust bearings in their motors.

In a similar vein Mr. Dawson commented on oiling systems for the long pump and driver combinations now appearing in power plants. The major problem was one of oil drainage and as the units became larger separate oil systems need to be developed to handle the driver and the pump.

Bypass and warm-up lines were the last two of the problems covered in this paper and in each instance recommendations as well as the author's observations were presented.

J. A. Tillinghast, American Gas and Electric Service Corp., in his paper, "Application of Single Turbine Driven Feed Pumps to 225,000-kw Generating Units," pointed out that the use of a single turbine driven boiler feed pump has several advantages: (1) Initial plant investment per net kw is reduced. (2) As applied in the steam cycle finally selected, cycle performance is improved. (3) For a given main turbine generator rating, plant capability is increased approximately 2 per cent (for a 2000 psi cycle) by elimination of auxiliary power use by the boiler feed pumps. (4) The unit system philosophy of one turbine and one boiler which has been



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continually developed on the AG&E System, is further implemented by the use of one boiler feed pump. (5) Variable pump speed for flow control is ideally achieved with a turbine drive. (6) High rotative speed suitable for large capacity, high head pumps is economically obtainable. (7) Hp heater tube design pressures may be reduced since the tubes will not be subjected to the full speed pump shutoff head. (8) Overload capacity is available in a variable speed pump in which the upper speed is not tied to some synchronous speed.

A single full capacity turbine driven pump has several limitations, however, which must be carefully evaluated. (1) The availability of the whole unit, 225,000 kw in each of seven units in the present case, is tied to the availability of the single feed pump and its turbine drive. (2) A motor driven startup pump must be provided to start the unit. (3) Operation of the pump during start-up requires more control than with motor driven pumps.

The author reported his company reviewed operating records of older turbine driven pumps on their system, as well as operating records of high pressure, high capacity boiler feed pumps which had been installed with motor drives in more recent plants, and also the company carried out extensive discussions with turbine manufacturers to obtain their experience with turbines of similar arrangement, size, speed and steam conditions. All of these studies indicated to the author's company that their pioneering step would be amply supported by excellent availability of the pump and turbine, fully commensurate with that of the boiler and main turbine, especially if constant attention in every design detail were given to improving reliability. In addition to high availability, boiler feed pumping equipment must be highly flexible to meet all operating conditions. Studies indicated that automatic and remotely controlled devices could be applied to a turbine driven feed pump so that it would have a speed of response better than that of the previously used feedwater regulating valves and an ease of operation nearly equal to that of a motor driven pump.

The decision to use steam turbine driven boiler feed pumps is made mainly on the basis of initial investment and change in net plant output. Once turbine drives have been selected there are several locations in a cycle where they may be fitted in. In this case, the location chosen is the one wherein extraction and exhaust from the boiler feed pump turbine serve three feedwater heaters. This supplied these feedwater heaters with lower temperature steam which improves the overall thermodynamic performance of the cycle and reduces appreciably the maximum shell design temperature of the feedwater heaters. The first extraction from the boiler feed pump turbine at approximately 275 psia, at full load, serves the No. 7 heater. The second extraction at approximately 175 psia, serves the No. 6 heater. The exhaust of the turbine is connected to the No. 5 heater and to the main cross-over between the high and low pressure sections of the main turbine. At full load the cycle is designed so that the exhaust flow from the boiler feed pump turbine nearly equals the No. 5 heater steam requirements. At less than full load, however, the turbine exhausts more steam than the heater can absorb and a tie-line is required to dispose of this excess steam through the low pressure section of the main turbine.

The author closed out his paper with further cycle design data and comments on controls, start-up and pump testing.

A. G. Mellor of General Electric Co. teamed up with **E. L. Pace** and **J. F. Ransom,** also of G.E., to present a paper "Economics of Turbine Drives for Boiler Feed Pumps" which supplied additional information on this general subject discussed by Mr. Mellor and Mr. Ransom with two other authors in an earlier paper at the recent AIEE Meeting in New York and published in its entirety in COMBUSTION, Feb. 1956, p. 46.

These authors opened by commenting that for many years it has been the general practice to use 3600 rpm motors for boiler feed pump drives but recently there has been considerable interest shown in the use of steam turbine drives. In general, motors have proved to be more economical for the size of generating units and steam pressures that have been commonly used. The renewed interest in turbine drives has resulted from: (1) The increased boiler feed pump power requirements of recent larger size generating units operating at higher steam pressures. (2) These increased pump power requirements have increased the difficulty of designing a suitable auxiliary power system for all electric auxiliary drives. (3) Boiler feed pumps have recently become available which are designed for speeds above 3600 rpm and these new pump designs are more economical particularly for higher pressure units.

This paper was prepared to serve as an aid in determining the economic application of motor and turbine drives for boiler feed pumps, and as such presents economic comparisons of the two types of drives and also a discussion of suitable cycle arrangements.

Do engineers blow too much?

Of course it's better to blow boilers too much than too little. But it does waste money to blow unnecessary heat units down the drain—enough usually to pay in just a few months for a modern system of precise, carefully-controlled, continuous blow-down. To get all the facts gamble a stamp for a copy of the booklet on the Madden Orifice Meter; write to *The Madden Corp., 1543 W. Morse Ave., Chicago 26, Ill.*

You and the Engineering Shortage*

By JOSEPH W. BARKER

President, The American Society of Mechanical Engineers

SOME people tend to express the engineering shortage in terms of the difference between the rates at which we and the Russians are training people. That is an important index, but it should be remembered that we have an absolute shortage of more than 50,000 engineers and scientists to fit into our peacetime economy. Last year we graduated 4000 fewer engineers and scientists than we needed just to replace the number of industrially employed scientists and engineers who retired or died. We would be in trouble even if we had an ironclad guarantee of peace for the next decade.

Unfortunately, we have no such guarantee, and so the shortage has military-political significance, as well as economic. You know the figures. Over the past 25 years, the Russians have turned out about three engineers for every two of ours. Last year, the ratio was about two to one. In addition to these specialists, the Russians are training a vast army of second-line technicians. What is more, they are feeding their people into the giant digestive system of Soviet economics that takes in heart and brain and converts them into bone and muscle.

We have recently witnessed a great debate—it is not over yet—on the pace of our guided missile program, with much conjecture as to whether we are falling behind the communists in this area. Whatever the answer, we are not going to increase our rate of progress merely by means of stepped-up appropriations. The greatest scarcity is in the supply of that rare commodity, the trained and creative mind. That is a scarcity that cannot be solved overnight, by Congressional action.

What is causing this problem? I believe it begins in the elementary schools and comes to a head in the high schools, where the young student decides what he wants to be, and begins electing subjects to prepare himself for his future.

In part, the difficulty is the result of a statistical impasse. Just about all the children of school age today were born in the 1940's, when, for the first time in the history of America, the rate of population growth showed a sharp upturn—twice as high as in the previous decade.

To teach our children, we are relying in large part on the generation of the 1930's, when the net increase in United States population was smaller than that of any decade since the 1860's, and the smallest in our history in terms of percentage. You don't have to be much of a statistician to see that the problem threatens to get considerably worse before it gets any better.

Not only do we have more children around today—more of them are going to school, for more years, than ever before. In 1900, only 11 per cent of the children in the 14-to-17 age bracket went to high school. Today the figure is 80 per cent. In the 18-to-21 age group, the percentage of college students rose from four per cent to nearly 30 per cent.

These young people do not have as many teachers as they should have. Often, their teachers are not as good as they should be. Worst of all, students in the high schools are not taking the courses that are designed to equip them for life in our changing society. They are electing courses that will get them through school with a minimum of intellectual nourishment, just as certain people of Asia eat mud and get a comfortable feeling in the stomach, but not much in the way of nutrition. Dorothy Thompson, in a recent column, pointed out that only four per cent of American high school students are studying elementary physics, seven per cent chemistry, 27 per cent algebra, and 13 per cent geometry, and that half our high schools do not even offer courses in chemistry and physics.

The Fund for the Advancement of Education has predicted that between now and 1970 we will have to find 16 to 25 new college teachers for every 10 now employed. They say that in order to fill our teaching needs we would need half of all the college graduates for the next 10 years. Obviously, we are not going to get them.

What is the answer? There is no single answer. Above all, I would emphasize to you that there is no national answer to this problem. It is going to have to be worked out locally, by people like yourself, in community after community across the nation. Maybe you think that is an impossible assignment. I say to you that the work has already begun, and we are seeing what can be done when clear thinking and sincere effort are applied.

Use of Teacher Aides

You might do what they did in Bay City, Mich. Like many other American communities, Bay City had a school problem. A study was instituted, with the help of Central Michigan College. They found that the teacher's traditional complaint of vast amounts of unnecessary work was justified.

They found that each of their 137 teachers was spending from an hour and a quarter to more than four hours every day on a combination of activities, which did not require professional teaching competence and could be included in the general phase housekeeping.

What did they do about it? They instituted a system for the use of teacher aides.

These teacher aides took roll call, checked papers, recorded grades, prepared materials for teaching, gave first aid, supervised home rooms—all the dozens of things that take so much of the teacher's time without requiring any of the teacher's special talents.

What was the result? They found that the new system made it possible for the teacher to spend an average of 23 per cent more time on activities closely related to instruction. She spent 20 per cent more time making assignments. Recitation time increased over one full hour per day. Teachers spent 41 per cent more time in supervision.

They polled the parents and found that one hundred per cent of them felt their children were enjoying school more, and 83 per cent felt that their children were learning more, while the other 17 per cent thought they were learning at least as much. All of the parents wanted the program continued. Of the pupils, 94 per cent said they liked the plan, and 98 per cent said they would want to be in a room with a teacher aide the following year. I suppose the small remainder consisted of those who resented the fact that the teacher had 20 per cent more time to make assignments.

* Excerpts from a talk delivered at the President's Luncheon, 1956 ASME Spring Meeting, Hotel Multnomah, Portland, Oregon, March 19, 1956.

The plan had another happy consequence: Many of the original aides enrolled in programs intended to prepare them to become full-fledged teachers.

Pooling Science Teachers

That is one solution. It is not a complete solution, and it may not be the best solution for your schools. In Ohio there were three high schools that were worried about the caliber of instruction in science courses. They, too, hired teacher aides. In addition, they hired three topnotch instructors, one each in physics, chemistry and mathematics. These three moved from school to school, like circuit riders, giving each school a level of competence in those three courses that it could not have afforded on its own. It should be remembered that, of America's 28,000 high schools, 22,000 have fewer than 500 students. Obviously, the smaller schools cannot all afford to hire top-quality teachers for every course. Maybe the answer lies in pooling parts of their faculties.

Another place where local businessmen have given a major assist to the schools is in the area along the Niagara River, in western New York. Industries in that area have set up refresher courses for high school science teachers. These classes are conducted at a single center. Teachers are given mileage allowances for transportation, and they get credit from the State Department of Education for their work. The companies are happy to cooperate, because it means better instruction in the high schools, and even if the students do not go on to college, they are going to be better workers because of that instruction.

In some areas, it might be practical to have engineers volunteer to devote, say, three hours a week to teach one class in mathematics or science. In addition, we have an increasing reservoir of engineers and scientists who have passed the mandatory retirement ages for their companies, but who are capable of many years of community service as teachers. Whatever legal barriers keep them out of the classroom should be removed.

Teaching Salaries

Teacher pay is certainly an obstacle. What happens when a high school science teacher sees a newspaper ad offering $400–$450 a month for a new engineering graduate, and compares it with his own $250 or $300 a month? What often happens is that he gives notice, and that is not good for his pupils, his school, or the nation as a whole. Taking the long-range view, it is not even good for the company that hires him away.

The president of the University of Delaware has told of the case of one of his seniors who had planned to become a high school science teacher, but was hired by a large corporation at a salary of almost $6000 a year. That was more than he could ever earn in the public schools of Delaware, under the existing scale. It was a thousand dollars more than they were paying to assistant professors at his own school, and it was almost as much as they paid to associate professors with Ph.D. degrees and years of experience behind them.

It seems one of the paradoxes of our economic system that we pay all our teachers according to the same yardstick. I admit that it would create certain personnel difficulties if you paid more to a teacher of chemistry than you did to a teacher of French. The simple truth, though, is that industry is not offering large salaries to teachers of French. We should realize that the educational system of the nation is not immune to the laws of supply and demand. We will have to abandon the "lock-step" pattern of teacher pay if the schools are to compete successfully with private firms for instructors in mathematics and the sciences.

Another thing we must do is to get word to the vocational counselors that the study of engineering is a good thing. One of the reasons for the present shortage is that these same counselors, during and immediately after World War II, took to heart the predictions that we would not be able to convert to peacetime production without a serious depression, and that there would be a glut of scientists and engineers.

Well, they were wrong, and so were the planners whose advice they took. Some of the counselors, though, may not yet have realized their error. They may not have heard that there are some 5000 firms today that have recruiting teams in the field looking over the approximately 350,000 students who will get bachelor's or master's degrees this year, and that the demand for engineers is higher than it has ever been. They may not have heard about the school that reports 12 to 15 job offers for each of its engineering seniors.

You should tell them. You should tell them that Standard Oil Company of Indiana has assigned 15 of its topflight research people to go around the country seeking out engineers and technicians, that General Electric Company is looking for 2000 technicians, that General Motors is looking for 900 engineers, that pay is at an all-time high, and that the number and variety of opportunities is greater than ever. In short, there never was a time when it made so much sense to prepare yourself to become an engineer.

And what will we do about it? I am

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not the first speaker to get up and tell an audience that there is a shortage, that we are falling behind the Russians in the race to produce engineers and scientists. There have been some results, but they have been far short of the mark. Sometimes, when I grow discouraged, I think of the Bandar-log, the Monkey-Folk of Kipling's "Jungle Book." Do you remember the words of Baloo the Bear?

"They have no law," he said, and he concluded, "they boast and chatter and pretend that they are a great people about to do great affairs in the Jungle, but the falling of a nut turns their minds to laughter and all is forgotten."

Now, you are not the Bandar-log, and I am not Baloo the Bear, but I fear that we are all going to go the Bandar-logical way unless we soon turn our serious attention to the problem of training our young people to live and work in the world that we are making for them.

New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Regenerative Turbine Pumps

A 12-page pamphlet, No. 107, which describes 19 models of two-stage regenerative turbine pumps and contains illustrated photographs and numerous cross-section diagrams illustrating the principle of operation, has been made available by the Roy E. Roth Co. Also included are data on mechanical seals available, installation dimensions and performance tables covering the performance of these pumps.

Two-stage Pumps

Bulletin No. C-1054 issued by Economy Pumps Div. of C. H. Wheeler Mfg. Co. describes Wheeler-Economy two-stage Type DMD pumps. Construction features are illustrated, including dimension tables for various pump sizes. Designed in sizes from 2 in. to 10 in., discharge for capacities to 4000 gpm and for heads to 750 ft. they are highly efficient, compact, rugged.

Solenoid Valves

The A-P Controls Corp. announced the release of a 6-page, 2-color bulletin covering the entire range of A-P solenoid valves. These valves designed for use with liquids, gases or refrigerants can be used for stop and start operations, mixing and blending, metering or measuring, controlling pressure differential, controlling pressure, and temperature and flow. Information on proper selection, features, coil construction, lift ratings, coil frequencies and liquid capacity and typical applications are listed in the new bulletin.

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Flexible Pipe Connections

"ExpandZorber," a complete line of flexible pipe connections used to solve vibration and expansion control problems in industrial and process piping, is described in catalog No. EZ-55 released by T. R. Finn & Company, Inc. The catalog describes pressure and temperature ranges of application, lists dimensions and specifications, as well as illustrating the various types of special-purpose joints available. Complete selection factors and installation procedures are also given.

Handling Valves

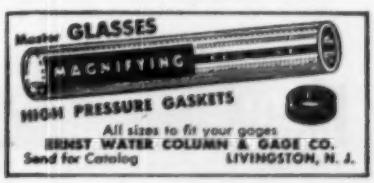
Data sheet DVa available from the Allen-Sherman-Hoff Co. covers the design, operation and advantages of A-S-H Type C materials handling valves. This 4-page bulletin uses photographs, schematics and line drawings to illustrate valve construction and operation. The advantages of Type C valves in A-S-H pneumatic ash handling systems are listed.

Steam Turbine Arrangement

Advantages of close-coupled design, pioneered by Allis-Chalmers, to reduce the floor area of high capability cross-compound reheat steam turbine generator units are discussed in a new eight-page Bulletin No. 03R8221 released by Allis-Chalmers Mfg. Co. The bulletin is authored by C. D. Wilson, engineer-in-charge of steam turbine design at Allis-Chalmers and was the subject of a paper presented at the 1954 Annual Meeting of the ASME.

Water Treatment

Prepared with the assistance of leading water treating consulting firms, the attractive Milton Roy Co. Bulletin 953 describes in 24 pages how controlled volume pumps are used in typical industrial water treating systems. Typical water treating processes described include coagulation systems, lime soda softening, hot process softeners, demineralization, and various types of



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boiler water treatment systems. Thorough analysis is given to cooling tower water treating problems as well as methods and systems for waste and sanitary water treatment.

Product Catalog

A catalog recently released by The Allpax Co., Inc., contains a complete line of Allpax rod and sheet packings, gasket cutters, and accessory items to meet most every industrial requirement. In addition to the general service packings, there is a complete line of braided, semi-metallic, and high-pressure packings. Each style of packing is thoroughly, yet briefly, described as to construction, applications and forms.

Motorpumps

An exceptionally attractive 24-page motorpump bulletin, Form 7093-E, has been released by Ingersoll-Rand Co. This bulletin covers their entire line of close-coupled motorpumps from ¼ to 75-hp sizes for delivery of 5 to 2800 gpm, and is designed to make it easy to select the correct size and model. A visual and concise index shows the basic classifications of pumps covered with their specifications.

Nuclear Reactor Simulator

A 4-page folder, No. ND46-70-700 (2), published by Leeds & Northrup Co., describes how their nuclear reactor simulator electronically synthesizes the operating characteristics of most reactor types, and reports that such a duplication is possible at a small fraction of the costs involved in building and operating an actual reactor. Photos illustrate the instrument's chief components, reported to be identical to those used in research reactors presently in operation. The theory of the simulator's operation is amplified by block diagrams of the complete system.

Two-Stage Pump

Allis-Chalmers Mfg. Co.'s two-stage pumps for boiler feed and other high pressure applications are described in the company's bulletin No. 52B6105C. Available in close-coupled and frame-type construction in capacities to 300-gpm at heads of from 300 to 550 ft at temperatures to 250 F, the pumps are suitable for boiler feed, humidifier, air conditioning, high head building, and mine service, as well as for gathering loading and pipeline operations in the oil fields.

Telemeter Receivers

The Bristol Co. has recently made available Bulletin M1710 which describes their miniaturized metameter

telemeter receivers. These can be used in graphic panel arrangements and are available either as indicators or strip-chart recorders, and occupy a panel space only 5 in. square.

Pneumatic Regulators

Conoflow Corporation, manufacturer of valves and controllers for the process industries, has issued Bulletin H-2, an 8-page booklet listing a complete line of precision-made pneumatic regulator equipment including filter-regulator combinations, filters and regulators, relays, purge assemblies and control panels. This descriptive, indexed bulletin is well illustrated with cross section and dimension drawings, and gives typical applications of use.

Reference Folder

"Facts About Titanium," a folder released by Arthur D. Little, Inc., contains a list of the commonly available titanium alloys and their compositions, forming and welding methods, heat treatment and machining information, as well as current and projected prices and other pertinent data. A brief comparison of titanium properties with those of a stainless steel and aluminum alloy is also included.

Ray Projector

A portable gamma ray projector with decided advantages of economy and operation over conventional X-ray equipment used in industrial radiography is the subject of an attractive 24-page booklet recently made available by The M. W. Kellogg Co. The new projector, as described in the booklet, offers a high degree of penetration yet is safe to operate, costs only a fraction as much as comparable X-ray equipment.

Motor Scraper

Engineering, design, construction and mechanical features of the new Allis-Chalmers TS-360 motor scraper that make it a "big-capacity" earth-moving unit are outlined in the new two-color catalog MS-663 available from the Tractor Group, Allis-Chalmers Mfg. Co. Photographs and drawings assist the reader to understand better the many advances incorporated in this 20 cu yd heaped or 15 cu yd struck capacity motor scraper powered by the 280 hp A-C diesel engine. Operator comforts that add to productivity capabilities of the TS-360 are also outlined, and complete specifications of the unit are included.

Drive Selection

A 74-page booklet entitled "Tex-Book" carrying handy multi-color tables

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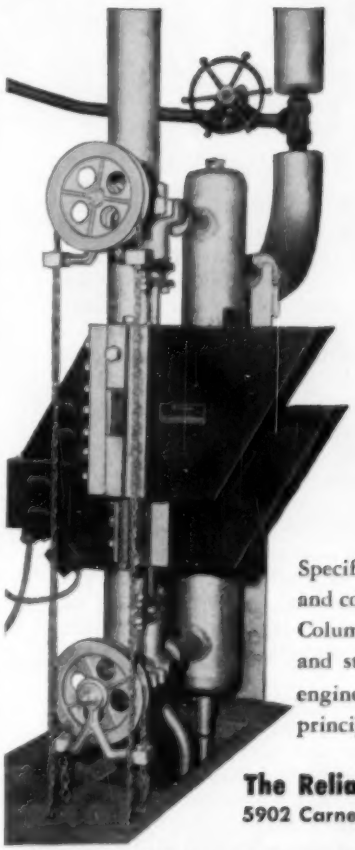

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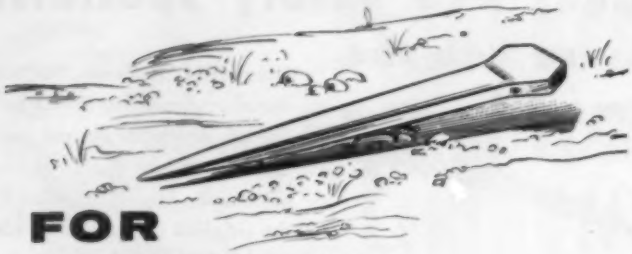

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Something that wasn't there once cost a king his life.

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for quick and easy selection of constant speed "Texrope" V-belt drives has been released by Allis-Chalmers Mfg. Co. In addition to providing selection tables for A, B, C, D and E section "Texrope" belts, handbook No. 20P40 features valuable information on design features, basic drive principles and technical data on sheaves as well as helpful hints for economical, safe and dependable operation of V-belt drives.

Refractories

Refractories Engineering & Supplies, Ltd., of Canada have recently made available a new brochure entitled "Furnace Life at Your Fingertips" which is of particular value to American firms bidding on or planning Canadian construction projects. The brochure describes refractory installation facilities, manufactured products and warehouse supply services available in the provinces of Quebec and Ontario.

Pyrometer

"Photoswitch Photoelectric Pyrometer," Bulletin PT 556, has been made available to industry by Photoswitch Division, Electronics Corp. of America. This 4-page illustrated pamphlet contains descriptive data, specifications and dimensions on Photoelectric pyrometer type P2T which provides new and greater flexibility.

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FIG. 29 Cylinder with Impeller

FIG. 17-28 Cylinder

FIG. 215 Flanged

FIG. E-57 Double Window

FIG. 212 Visibility Welding Neck or Screw

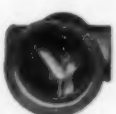

FIG. E-811 Flapper

FIG. E-1810 Rotating Wheel Type

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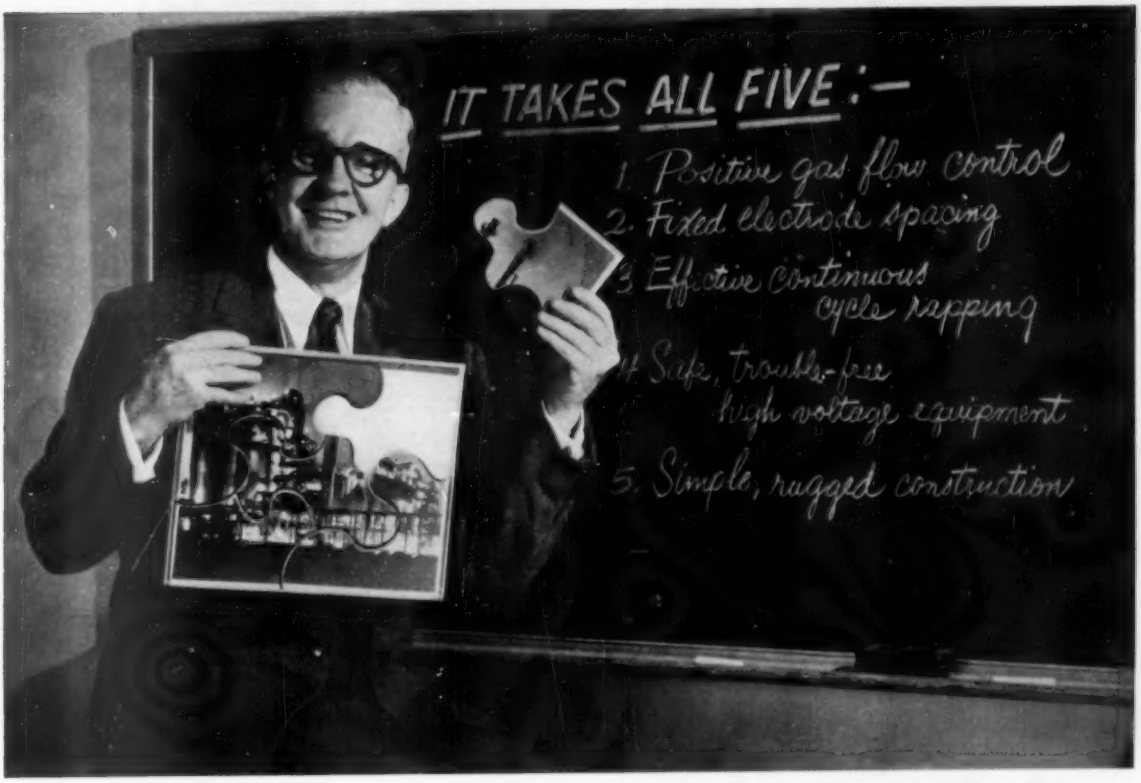
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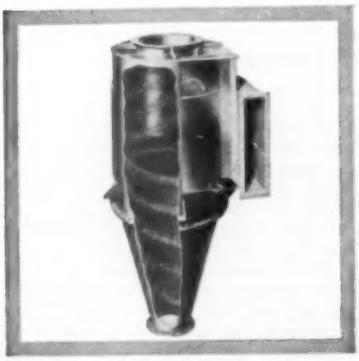
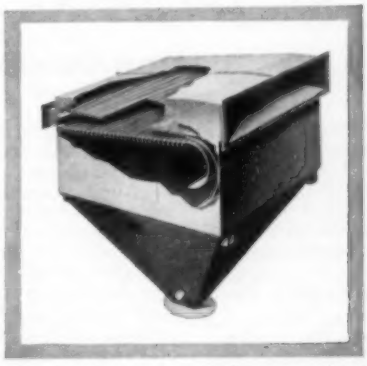


Buell Cyclone Collectors are noted for their efficiency, too. Here are exclusive reasons why: shave-off design which harnesses back-flow and puts it to work . . . plus extra large diameter design to prevent "plugging."



Buell "LR" Fly Ash Collectors are ideal for low and high pressure boiler operations up to 2000 BHP, with either natural or mechanical draft. Check them for high efficiency, simple design, compactness, flexibility in layout.

FREE BOOKLET!
"The Collection and Recovery of Industrial Dusts"
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buell

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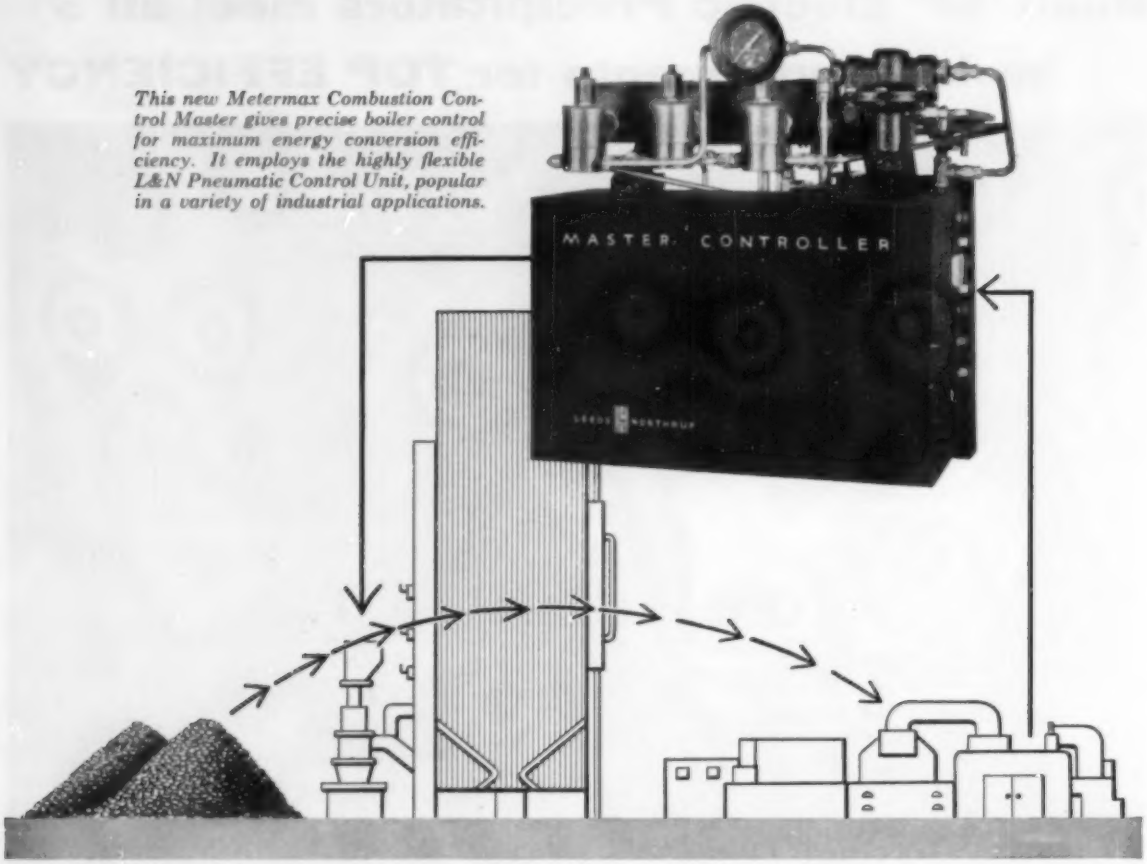
This new Metermax Combustion Control Master gives precise boiler control for maximum energy conversion efficiency. It employs the highly flexible L&N Pneumatic Control Unit, popular in a variety of industrial applications.



Let this "cost-conscious" brain

HELP SOLVE YOUR COMBUSTION CONTROL PROBLEMS

■ The widely-used Metermax Combustion Control now features this new Master Controller which gives you precise, stable boiler control over a wide load range. Because of its unitized design this Master coordinates the three fundamental control actions. Thus, you're assured of a precise blending of: *proportional action* to meet boiler load changes, *reset action* to maintain a constant steam pressure at all loads, and *rate action* to gear response to the speed and intensity of load swings.

You get wide-range stability because the Master automatically "modulates" its own response as boiler load decreases to reduce control action at low loads for maximum stability. Your proportional, reset, and rate settings, once made to meet a given boiler load condition, are correct for all loads . . . automatically. You need not change or compromise your initial settings. These settings are easy to make, with an independent, calibrated dial for each action.

Boiler operators find this Master easy to work with. First, they can transfer to automatic quickly, because they can balance it to existing boiler conditions simply by turning a single, panel-mounted knob. The transfer is "bumpless," there's no boiler upset . . . no operator attention is needed after transfer. Second, operators get instant action from the Master because there are no long control tubing runs. Control circuits are electric all the way from the control room to the "control center" where the Master and the individual Metermax Controllers are located. This, plus electric transmission to the electric drive units, provides instant response. And third, the Master adjusts itself as load decreases, for low-load stability, thus relieving the operators of this additional duty.

Precise control . . . wide-range stability . . . fast response . . . ease of operation. That sums up what you can expect of Metermax Combustion Control.

For more information on this Metermax Master, write to Leeds & Northrup Company, 4972 Stenton Ave., Philadelphia 44, Pa.

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STEPS UP BOILER PERFORMANCE

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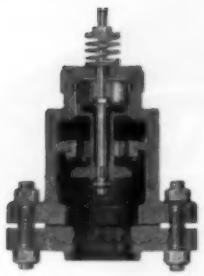
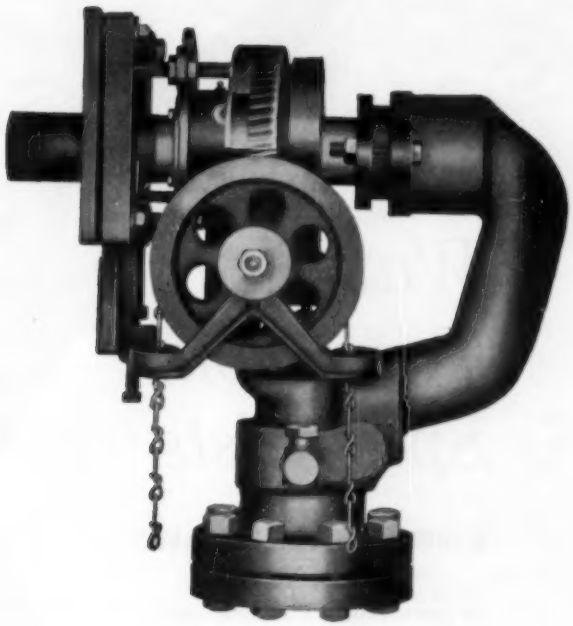


Bayer Balanced Valves are famous for their long life and continued tightness



Bayer Single Chain Balanced Valve Soot Cleaner

WITH THE Bayer Balanced Valve Soot Cleaner the balancing chamber above the piston disc impounds steam when the valve closes, thus relieving valve parts from shock. The valves remain *steam tight* because the dashpot action causes the valve to seat gently. Unbalanced valves close with a hammer stroke and soon become leaky.

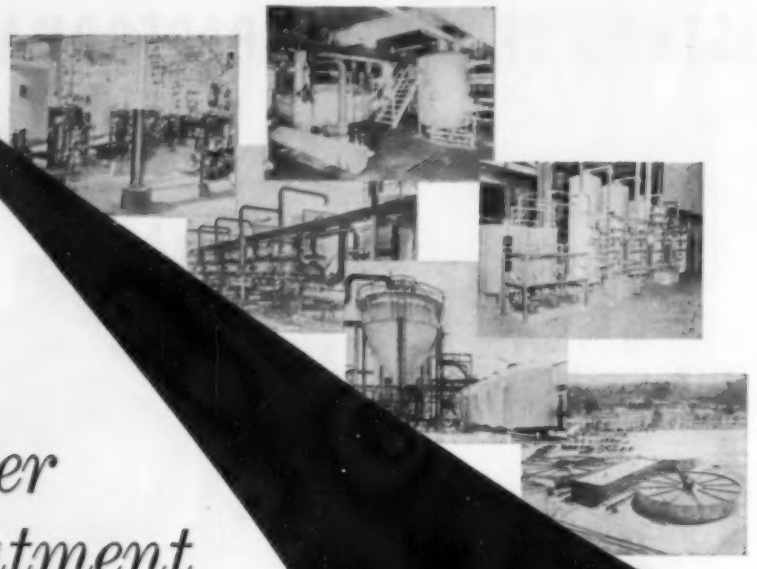
When stationary elements are used the Bayer stationary balanced valve head may be furnished. Thus all the cleaning elements of the entire soot cleaner system can be controlled by the Bayer quick-opening Balanced valves. This gives a uniform or standard valve controlled system and in addition, when high pressures require a reduction in pressure *at each individual element* this Balanced valve unit, whether used with a stationary or a revolving element, can be fitted with an integral orifice plate valve.

Piping connections can be kept in the same plane and undesirable bends or fittings avoided when the Bayer Balanced Valve is installed with both stationary and revolving elements.

Valve parts are standard and interchangeable and when high pressure heads are fitted with orifice plate regulating valves these parts are also interchangeable.

THE BAYER COMPANY

SAINT LOUIS, MISSOURI, U. S. A.



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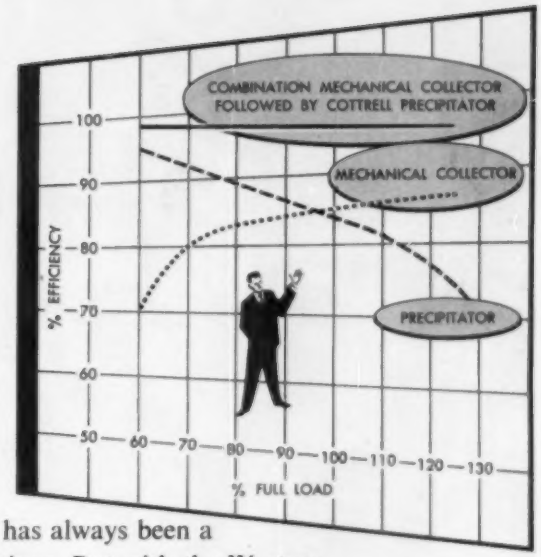
Advantages of the Western Precipitation CMP Unit

for recovering fly ash in power plant operations



The control and recovery of fly ash has always been a troublesome problem in power plant operations. But with the Western Precipitation CMP unit, new economy and efficiency in the solution of fly ash problems are now being made in both small and large plants.

The CMP is backed by experience unequalled in the industry. Almost a half century ago Western Precipitation pioneered the first commercial application of the now-famous Cottrell Electrical Precipitator to recover suspensions *electrically*, and this equipment is still unsurpassed in its field.

Subsequently, to provide efficient fly ash recovery for low cost installations, Western Precipitation also pioneered the first multiple small tube mechanical recovery unit—the Multiclone Collector—and this unit promptly gained widespread recognition for the new efficiencies it brought to mechanical recovery processes.

From these years of experience gained in *both* electrical (Cottrell) and mechanical (Multiclone) recovery installations, Western Precipitation pioneered another new development—the CMP Unit—*a unit that combines in one compact installation many of the best features of both electrical and mechanical recovery methods.*

In a typical CMP Unit, the stack gases first pass through a Multiclone section where the heavier materials are removed *mechanically*.

The partially-cleaned gases then pass through a Cottrell section where the very small particles are removed *electrically*.

This arrangement offers several important advantages. Removing the heavier particles by Multiclone permits the bulk of the recovery operation to be performed with relatively low-cost equipment. Using a Cottrell for the final clean-up insures unusually high recovery efficiency—approaching theoretically perfect, if desired. Thus, the CMP combines high recovery efficiency with low total cost.

But that's not all. The CMP has the further advantage that the efficiency curve of the Multiclone portion complements that of the Cottrell portion (as shown in the chart above)—*therefore the overall CMP efficiency remains practically uniform at all boiler loads.*

At low boiler loads the recovery efficiency of the Cottrell is highest . . . and at high boiler loads the Multiclone reaches its maximum efficiency. But, by combining the two types of equipment into a *single* CMP Unit, the efficiency curve remains almost flat, regardless of the boiler load.

With CMP equipment, even small power plants can now afford adequate fly ash recovery. However, this fact is all-important . . . full benefit of the CMP principle can be obtained only by a proper balance between the mechanical and electrical sections to fit the individual requirements of *each individual* installation. And no organization is better equipped to provide this critical "know-how" than the *one* organization that has had far more experience than any other in BOTH *electrical* and *mechanical* recovery methods . . . WESTERN PRECIPITATION CORPORATION!

This, the industry's finest recovery experience, is as close to you as your telephone. May we supply further details?

COTTRELL Electrical Precipitators
MULTICLONE Mechanical Collectors
CMP Combination Units
DUALAIRE Reverse-Jet Filters
HOLO-FLITE Processors

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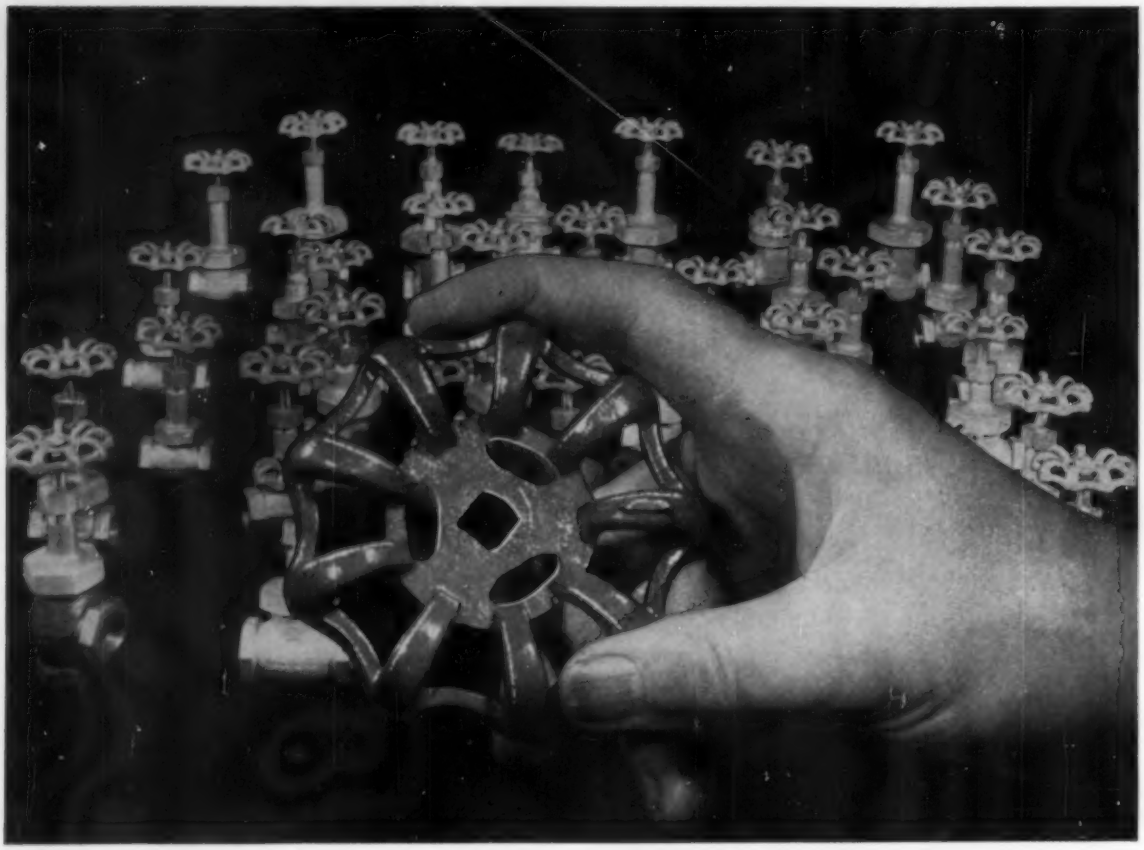

One handwheel fits 39* different valves

*Walworth Handwheel No. 16 fits these Walworth Bronze Valves:	
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1½"	No. 2, 3, 4, 11, 12, 14

Only Walworth Bronze Valves give you this degree of interchangeability

With standardized Walworth Bronze Valve parts you maintain the greatest number of valves with the smallest inventory of basic parts. Handwheels are just one example. Fourteen different sizes of handwheels are all you need for fifty lines of gate, globe, and angle valves, involving 420 individual valves.

The Walworth system of interchangeability of parts for Bronze Valves is unsurpassed by any manufacturer in the field. In addition to Bronze Valves, Walworth produces valves and pipe fittings of iron, steel, special alloys, and rigid polyvinyl chloride (PVC).

Learn more about Walworth interchangeability. Contact your local Walworth Distributor or nearby Walworth Sales Office. Ask for literature.

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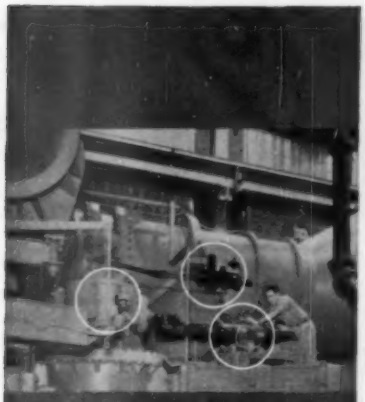
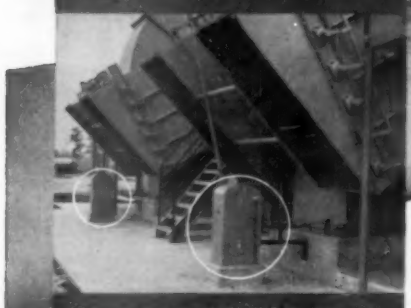
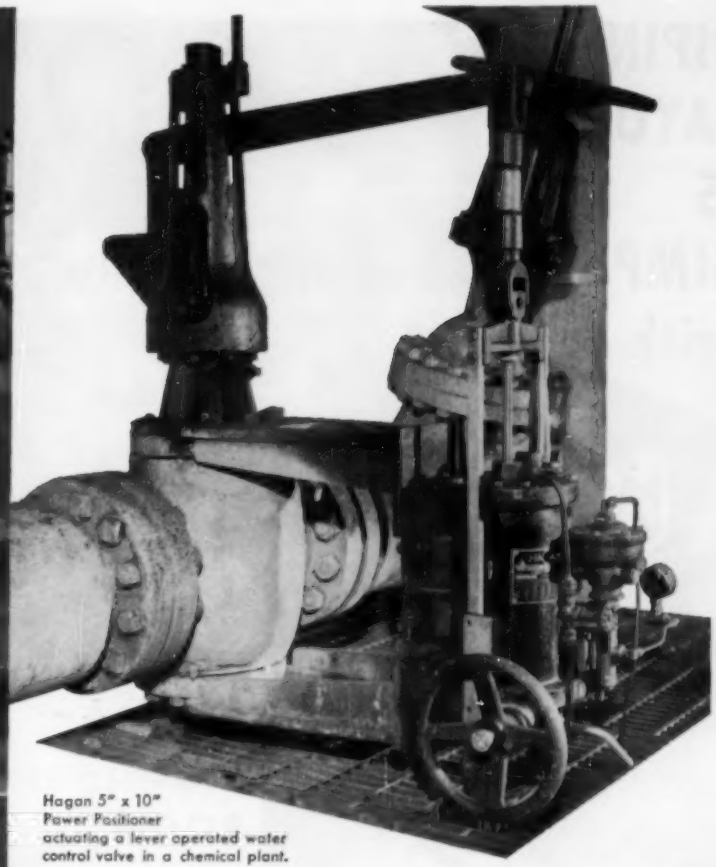


Two 8" x 20" and one 5" x 20" Hagan Power Positioners operating plug valves on a wind tunnel in an aeronautical test facility.



Louvers on forced draft fans operated by Hagan 6" x 10" Power Positioners. Note outdoor installation.



Hagan 5" x 10" Power Positioner actuating a lever operated water control valve in a chemical plant.

HAGAN POWER POSITIONERS

HIGH PRECISION—LOW MAINTENANCE!

8" x 14" Power Positioner operating louvers of forced draft fan on a large public utility boiler.

Hagan Power Positioners provide the "muscles" for thousands of control applications in every type of industry—wherever torque and positioning accuracy requirements are severe.

Hagan Power Positioners are economical, both in first cost and in the low maintenance costs which result from their uncomplicated design and strong construction. Many Hagan units are still giving trouble-free, dependable service after years of exposure to rigorous conditions, such as high ambient temperature (up to 160°), corrosive atmospheres, or outdoor installations.

Hagan Power Positioners can help you lower costs in all your final power drive needs. Write for Specification File TP-MFI for information on the full range of these powerful "Muscles for Industry."

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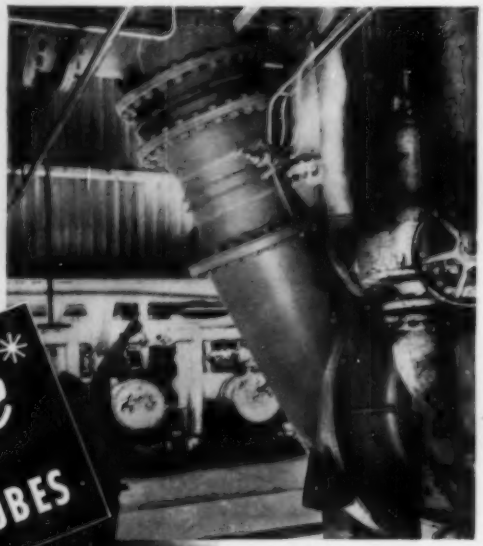
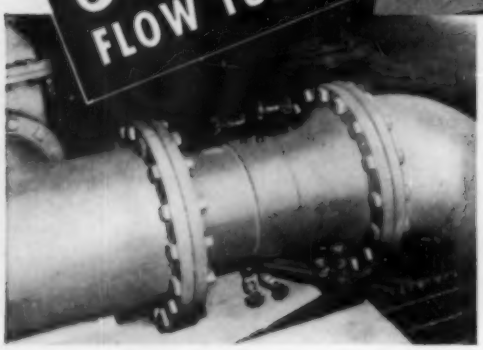
PIPING LAYOUT IS SIMPLER with Gentile* FLOW TUBES





...THEY NEED SO LITTLE ROOM

Gentile Flow Tubes are short. They need only minimum straight runs entering and following, and can be installed at practically any accessible point where flow conditions are reasonably steady.

Flow Tubes are furnished with individual head capacity curves, and for unusual piping arrangements, calibration curves for simulated conditions can be furnished.

Guaranteed

- Accuracy
- Minimum Head Loss
- Reproducibility

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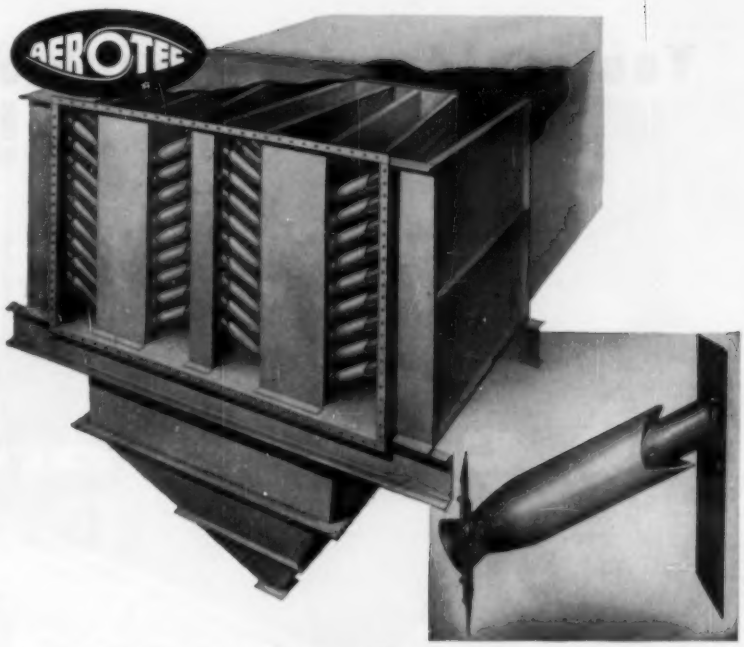

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- **Higher Efficiency**
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- **Simplified Field Erection**
- **Low Maintenance**

The new Aerotec 5" Tube of white cast iron assures extremely high dust collector efficiency and in service far exceeds tubes of other basic metals. Accelerated tests conducted by Aerotec engineers have proven conclusively that white iron is superior in reducing wear, even when caused by the most highly abrasive particles.

Tubes are factory assembled into "building block" elements to simplify field erection. In addition, the inherent design of the 5" Tube reduces the possibility of plugging, even at low temperatures, or when the fuel has a high sulphur content. Years of research behind the development of this tube now assure a collector that requires minimum maintenance.

For information about the new Aerotec Tube, call or write to The Thermix Corporation, Project Engineers for Aerotec.

Project Engineers **THE THERMIX CORPORATION** Greenwich, Conn.
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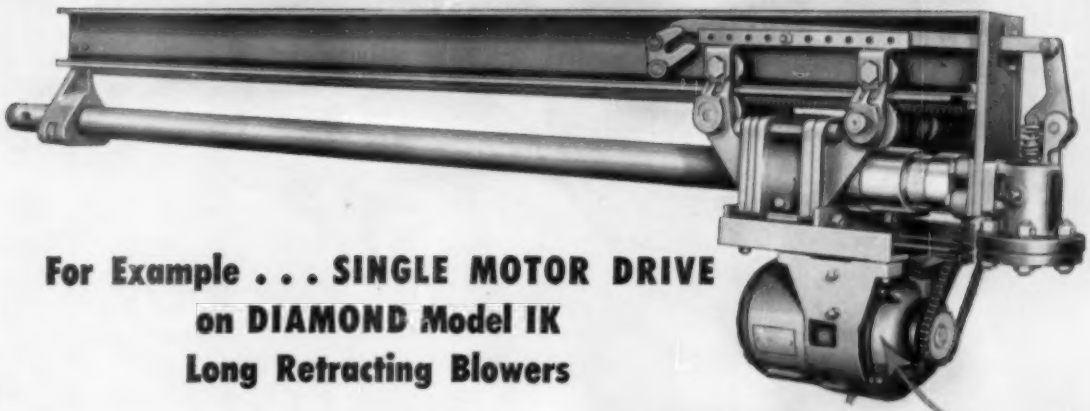
"Keep It Basic" "Avoid Unnecessary Complications"



For Example . . . SINGLE MOTOR DRIVE on DIAMOND Model IK Long Retracting Blowers

A Single Motor (air or electric) Both Rotates and Propels the Long Lance Tube

Diamond engineers have always felt that it isn't enough to design a mechanism that will do a particular job. It is also important to make that mechanism as simple and dependable as possible. It has been a Diamond policy for decades to *"keep it basic"* . . . to avoid unnecessary complications that make trouble for users.

Diamond Soot Blowers are simple, effective, dependable. Typical of this is the single motor drive on the Model IK Long Retracting Blower. One motor working through a simple system of rugged gears simultaneously propels the carriage and rotates the lance tube. The ultimate in simplicity and reliability, there is only one set of motor elements, one set of control elements, and one set of power supply facilities to operate and maintain. Long experience with all kinds of cleaning problems has demonstrated conclusively that there is a single universal cleaning pattern suited to substantially all conditions encountered.

Other important features of Model IK are the mechanically operated valve with adjustable pressure control, and the positive gear drive. For additional information ask for Bulletin 1080V.

DIAMOND POWER SPECIALTY CORPORATION

LANCASTER, OHIO

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Diamond

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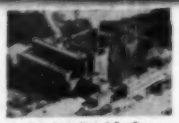

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Hickling Station

If your operations depend on piping you can depend on Shaw

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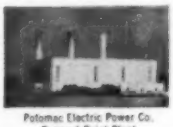

Potomac Electric Power Co.
Buzzard Point Plant

Ind. & Mich. Electric Co.
Tanners Crook Plant

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Pennsylvania Electric Co.
Seward Station, Unit 5

SHAW

piping specialist in Power Plant Construction

If you are concerned with the construction of a modern power plant, you realize the absolute need for specialization in all phases of the work. Particularly is this true of the fabrication and installation of the intricate piping which such a project requires. Only a specialist can provide the best in piping; that is, piping which is custom fabricated, properly installed, safely and economically designed for your specific needs. Shaw is such a specialist, qualified through years of experience to fabricate and erect power plant piping for any pressure and any temperature you require. Since 1893, Shaw has devoted its resources, its talents and its energies to this kind of specialization. That's why we say—if your operations depend on piping, you can depend on Shaw.

Shown here—and the names included are foremost in the industry—are some of the many power plants in which the piping is Shaw-fabricated.

Del. Power & Light Co.
Indian River Station

Ohio Power Company
Philo Station, Unit 6

Ind.-Ky. Electric Corp.
Clifty Cr. Sta., Units 1-6

Houston Lighting & Pr. Co.
Greens Bayou Station

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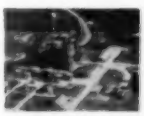
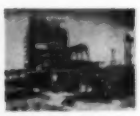
Deepwater Station, Unit 7



Houston Lighting & Pr. Co.
Webster Station



Houston Lighting & Pr. Co.
Sam Bertron Station

Ohio Power Company
Muskingum R. St., Units 1-2

Appalachian Elec. Power Co.
and Ohio Power Company
Philip Sporn Plant

BENJAMIN F.

SHAW

COMPANY

Main Offices and Plant: Wilmington, Delaware

Piping Fabrication and Installation Since 1893